भारतीय मानक **IS 16590 : 2023**

Indian Standard

तरल द्रुतशीतन पैकेज इकाइयाँ — विशिष्टि

(पहला पुनरीक्षण)

Liquid Chilling Package Units — Specification

(First Revision)

ICS 23.120

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Refrigeration and Air Conditioning Sectional Committee, MED 03

FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Refrigeration and Air Conditioning Sectional Committee had been approved by the Mechanical Engineering Division Council.

This standard is intended to define the testing requirements for measurement of performance and energy efficiency of liquid chilling package units using vapour compression cycle.

The manufacturers of liquid chilling package units offer a complex array of equipment to meet the diverse applications of markets. The complexity of the product offering precludes the testing of each and every model. However, in order to promote consistency in the representation of chiller performance by all manufacturers, this standard establishes uniform rating and testing methods.

This standard was first published in 2017. The title of the standard was modified through the first amendment.

This first revision of the standard has been contemplated with a view to incorporating the modifications and modify the test conditions based on the experience gained since the publication of its first edition. The major changes made in this first revision are as follows:

a) The scope of the standard has been modified;
b) Indian seasonal energy efficiency ratio (ISEER) definition has been added;
c) The standard rating conditions are revised (*see* Table 1);
d) The tolerance on the rating has been revised (*see* Table 2);
e) The accuracy of the measuring instrument has been revised (*see* Table 3);
f) The variation from the specified parameters for cooling capacity test has been modified (*see* Table 4); and
g) Indian seasonal energy efficiency rating condition is revised (*see* Table 7).

The minimum value of coefficient of performance (COP) and Indian seasonal energy efficiency ratio (ISEER) shall in no case be inferior than the value prescribed in the national regulation.

While formulating this standard, following standards were also reviewed:

AHRI Guideline 1997 E	Fouling factors: A survey of their application in today’s air conditioning and refrigeration industry
EN 14511-1 : 2022	Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors for space heating and cooling — Part 1: Terms and definitions
EN 14511-2 : 2018	Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors for space heating and cooling — Part 2: Test conditions
EN 14511-3 : 2018	Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors for space heating and cooling — Part 3: Test methods
AHRI 550/590 (I-P)-2020 with addendum 3	Performance rating of water-chilling and heat pump water-heating packages using vapor compression cycle
AHRI 551/591 (SI)-2020 with addendum 3	Performance rating of water-chilling and heat pump water-heating packages using vapor compression cycle
AHRI 370 : 2015	Standard for sound performance rating of large air-cooled outdoor refrigerating and air-conditioning equipment
ANSI/ASHRAE 30-2019	Method of testing liquid-chilling packages

(*Continued on third cover*)

Indian Standard

LIQUID CHILLING PACKAGE UNITS — SPECIFICATION

(First Revision)

1 SCOPE

1.1 This standard covers the general requirements and method of tests for the measurement of performance and energy efficiency of liquid chilling package units using vapour compression cycle covering all types and sizes for the rated voltage up to and including 250 V, 50 Hz a.c. for single-phase and up to and including 415 V, 50 Hz a.c. for three-phase power supply.

This standard is applicable to all positive temperature comfort cooling application ranging from 5 °C to 10 °C.

NOTE — Liquid chilling package units are also commercially known as chillers.

1.2 This standard covers full load and part load ratings test methods.

1.3 This standard does not cover the following:

a) Packages with condensing unit provided with heat reclaim;
b) Systems with a remote condensing unit;
c) Systems with an evaporative cooled condenser;
d) Condenser-less chillers;
e) Heat pumps;
f) Liquid chilling package units used in process industries;
g) Any applications related to defense or marine; and
h) Any applications other than comfort cooling in the built environment.

2 REFERENCES

The standards listed in Annex A contain provisions which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

3 TERMINOLOGY

For the purpose of this standard, the definitions given in IS 3615 shall apply, in addition to the following:

3.1 Bubble Point — Refrigerant liquid saturation temperature at a specified pressure. It is the temperature at which the first bubble of vapour forms in liquid refrigerant (saturated liquid) expressed in °C.

3.2 Condenser — A refrigeration system component which condenses refrigerant vapour. Sub-cooling of the refrigerant may occur as well.

3.2.1 *Air-Cooled Condenser* — A refrigeration system component that condenses refrigerant vapor by rejecting heat to air circulated over its heat transfer surface causing a rise in the air temperature. Sub-cooling of the refrigerant may occur as well.

3.2.2 *Water-Cooled Condenser* — A refrigeration system component which utilizes refrigerant-to-water heat transfer means, causing the refrigerant to condense and the water to be heated. Sub-cooling of refrigerant may occur as well.

3.3 Condenser Heat Rejection Capacity — The heat removed by the heat transfer medium of the condenser per unit of time (kW).

3.4 Cooling Capacity — Heat transferred from the liquid to the refrigerant per unit of time, in evaporator expressed in kW.

3.5 Coefficient of Performance (COP) — Ratio of the cooling capacity in kilo watts to the total power input in kilo watts.

NOTE — This definition of COP refers to chilling units only.

3.6 Dew Point — It is the temperature at which the first droplet of liquid forms in refrigerant vapour (saturated vapour). The evaporating and condensing temperatures should correspond to the mean of bubble and dew points.

3.7 Fouling Factor — The thermal resistance due to fouling on the fluid side of the heat transfer surface ($m^2.°C/kW$).

3.8 Fouling Factor Allowance — Provision for anticipated fouling during use, specified in ($m^2.°C/kW$).

3.9 Liquid-Chilling Packages — A refrigeration machine using the vapour compression cycle.

NOTE — Liquid-chilling packages may be operated with any type of compressor and be equipped with air-cooled and/or liquid-cooled condensers. Liquid chilling packages can be supplied with or without pumps.

3.10 Liquid Refrigerant Temperature — Temperature of the refrigerant entering the expansion device (°C).

3.11 Published Ratings — A statement of the assigned values of those performance characteristics, under stated rating conditions, by which a unit may be chosen to fit its application. These values apply to all systems of like nominal size and type produced by the same manufacturer. As used herein, the term 'Published Rating' includes the rating of all performance characteristics shown on the unit or published in specifications, advertising or other literature controlled by the manufacturer, at stated rating conditions. Performance data over the operating range of the unit at full load in the form of performance curves or catalog or output from a software selection code.

NOTE — The published ratings are the ratings declared by the manufacturer in any form as defined above.

3.11.1 *Standard Rating* — A rating based on test performed at standard rating conditions (*see* **6.3**).

3.11.2 *Application Rating* — A rating based on test performed at application rating conditions other than standard rating conditions (*see* **6.4**).

3.12 Saturated Discharge Temperature — For single component and azeotropic refrigerants, it is the saturated temperature corresponding to the refrigerant pressure at the compressor discharge (°C).

For zeotropic refrigerants, it is the arithmetic average of the dew point and bubble point temperatures corresponding to refrigerant pressure at the compressor discharge.

NOTE — The refrigerant saturation pressure is generally measured at or immediately downstream of the compressor discharge service valve, where discharge valves are used (*see also* Table 1).

3.13 Standard Barometric Pressure — Barometric pressure of 101.325 kPa (1 bar).

NOTE — *See also* note under Table 1 and Annex F.

3.14 Total Power Input of the System — Power input of all components of the unit in operation shall include:

a) The power input for operation of the compressor (kW);
b) The power input of all controls, safety devices, starters, and drives of the unit, including devices necessary for correct operation of the refrigerating circuit (for example oil pump, refrigerant pump) (kW); and
c) The power for fans for air-cooled liquid chillers (kW).

3.15 Sound

3.15.1 *Sound Pressure* (*P*) — Difference between instantaneous pressure and static pressure.

NOTE — Sound pressure is expressed in pascals (Pa).

3.15.2 *Sound Pressure Level* (L_p) — Ten times the logarithm to the base 10 of the ratio of the square of the sound pressure, p to the square of a reference value p_o, expressed in decibels.

$$L_p = 10 \lg (p^2/p_o^2) \text{ dB}$$

where the reference value, p_o, is 20 µPa.

NOTE — If specific frequency and time weightings as specified in IEC 61672-1 and/or specific frequency bands are applied, this is indicated by appropriate subscripts; L_{pA} denotes the A-weighted sound pressure level.

3.16 Type Test — A test or series of tests made on one or more sample of equipment and its components representative of production, for the purpose of checking compliance of the design of a given product with the requirements of the relevant standard.

3.17 Indian Seasonal Energy Efficiency Ratio (ISEER) — Ratio of the total amount of heat that equipment can remove when operated for cooling in active mode to the total amount of energy consumed by equipment during the same period.

NOTE — A single number part-load efficiency figure of merit calculated as per the method described in this standard at standard rating conditions.

3.18 Part Load — It is the percentage of part-load rated capacity to the full load capacity.

4 CLASSIFICATION

The liquid chilling packages shall be classified according to method of cooling of condenser as follows:

a) Air-cooled condenser; and
b) Water-cooled condenser.

5 GENERAL REQUIREMENTS

5.1 Construction

5.1.1 The unit shall be constructed with sufficient strength and rigidity to withstand normal manual and mechanical handling, transportation and usage without damage or failure.

5.1.2 All parts that require periodic cleaning or maintenance shall be easily accessible when the unit is installed in accordance with manufacturer's installation manual.

5.1.3 Self-tapping screws shall not be used for any load bearing parts.

5.1.4 All parts that constitute an accident hazard shall be suitably guarded.

5.1.5 The connections to moving or resiliently mounted parts and pipes shall be so arranged as not to foul or to transmit undue vibrations to other parts and shall be so designed as to prevent failure due to fatigue.

5.1.6 Water-cooled condenser shall have cleanable water passages, either by mechanical means or chemical or both. An opening shall be provided in the casing, so as to have access to passages bearing water, from either end, for the design amenable to mechanical cleaning.

5.1.7 All valves and refrigeration piping shall be properly clamped so as to avoid excessive vibration.

5.1.8 Structural construction parts shall be with corrosion resistive coating.

5.1.9 Compliance of requirements given in **5.1.1** to **5.1.8** shall be checked by inspection.

5.2 Safety Devices

5.2.1 The liquid chilling packages shall be provided with the following safety devices:

a) Electrical safety:
   1) Overcurrent relay;
   2) Single phasing and phase reversal prevention (wherever applicable);
   3) Emergency power OFF (EPO)/Isolator switch (wherever applicable);
   4) Leakage current cut-off; and
   5) Safety alarm for errors (wherever applicable).

b) Mechanical safety:
   1) High pressure cut-off;
   2) Low pressure cut-off;
   3) Freeze protection; and
   4) High pressure relief valve (wherever applicable).

The compliance shall be checked by inspection.

5.2.2 Terminal box for termination of cables to the chiller shall be the integral part of the chiller control panel. The terminal block connector shall be of appropriate size to connect the conductors of any suitable material.

5.2.3 Condenser heat exchanger guard shall be provided for air-cooled condenser.

5.3 Installation Requirements

The liquid chilling package manufacturer shall provide manual for installation, operation, maintenance, and safety precautions. For further details, (*see* **19**).

6 RATING

6.1 Standard Rating Conditions

Published ratings for all liquid chilling packages shall include the standard ratings, corresponding to the standard rating conditions shown in Table 1 within the operating limits of the unit.

6.2 Published Ratings

Published ratings shall meet the requirements of this standard. Performance ratings shall be based on test data or models derived from test data. Published ratings shall be presented in the form of a performance curve or catalogue or output from a computer selection code and shall include the following:

a) Name and address of the manufacturer;
b) Refrigerant name in accordance with IS 16656/ISO 817;
c) Unit type, model number, model number designations providing identification of the liquid-chilling packages to which the ratings shall apply;
d) Rated voltage, frequency, and phase;
e) Maximum starting current in ampere (A);
f) Full load current in ampere (A);
g) COP at rated condition;
h) Indian seasonal energy efficiency ratio (ISEER);
j) Sound pressure level (dB);
k) Fouling allowance — Published ratings shall clearly state the fouling allowance. Corrections and calculations for different fouling factors shall be made as per Annex B. Ratings shall be published using nominal fouled rating as per Table 1.

NOTE — In air cooled condensers, if variable speed condenser fans or fan staging is used, the manufacturer shall publish the capacities and COPs taking into consideration the different performance parameters according to the fan control of the unit.

Table 1 Standard Rating Conditions

(*Clauses* 6.1, 6.2, 6.5.2, 17.1 *and* 19.1)

Sl No.	Liquid/Air-Cooled Condenser	Liquid-Cooled	Air-Cooled
(1)	(2)	(3)	(4)
i)	Liquid/Air-cooled condenser:		
	a) Entering temperature	30 °C	Not applicable
	b) Δ T	5 °C	Not applicable
	c) Liquid-side fouling factor allowance	Nominal 0.044 m^2.°C/kW	Not applicable
	d) Entering dry-bulb temperature	Not applicable	35 °C
	e) Air-side fouling factor allowance	Not applicable	0.000 m^2.°C/kW
ii)	Evaporator liquid temperature:		
	a) Leaving	7 °C	
	b) ΔT	5 °C	
iii)	Evaporator fouling factor allowance:		
	a) Liquid-side	Nominal 0.018 m^2.°C /kW	
iv)	Barometric pressure	101.325 kPa	

NOTE — Air-cooled unit ratings shall be corrected to a barometric pressure (for air cooled units) of 101.325 kPa as per Annex F.

6.3 Standard Ratings

The standard ratings shall be as follows:

a) Total power input to chiller, kW;
b) Full load cooling capacity at standard rating conditions, kW;
c) COP at rated condition;
d) Indian seasonal energy efficiency ratio (ISEER);
e) Any two of the following:
  1) Entering evaporator liquid temperature, °C;
  2) Leaving evaporator liquid temperature, °C; or
  3) Liquid temperature difference through the evaporator, °C.
f) For all units without integral evaporator pump, evaporator liquid pressure drop (kPa) and for units with integral pumps the available static pressure (kPa);
g) Chilled liquid flow rate, l/s; and
h) Liquid-cooled condenser packages:
  1) For water-cooled units without integral pump condenser liquid pressure drop (kPa) and for units with integral pump the available static pressure (kPa);
  2) Any two of the following:
    i) Entering condenser water temperature, °C;
    ii) Leaving condenser water temperature, °C; or
    iii) Water temperature difference through the condenser, °C.
  3) Condenser water flow rate, l/s; and
j) Air cooled condenser unit:
  1) Entering air dry-bulb temperature, °C.

6.4 Application Rating

Application ratings (other than standard rating) shall include published ratings at full load and the range of conditions within the operating limits of the equipment which shall be presented in the form of a performance curve or catalog or output from a computer selection code.

The conditions and the operating limits are as defined below:

a) All condenser types — Leaving chilled water temperature for evaporators shall be 4.4 °C to 10.0 °C in increments of 2 °C or less and temperature difference between 2.5 °C and 8 °C;
b) Liquid-cooled condenser — Entering condenser water temperature 20 °C to 35 °C in increments of 2 °C or less and temperature difference between 2.5 °C and 8 °C; and
c) Air-cooled condenser — Entering condenser air dry-bulb temperature 20 °C

to 46 °C dry-bulb in increments of 3.5 °C or less and temperature difference between 2.5 °C and 8 °C.

NOTE — The rating conditions and the operating limits other than those prescribed above shall be mutually agreed upon between the manufacturer and the buyer.

6.5 Part-Load Performance Rating

6.5.1 Part load rating data shall be published or available upon request over the application rating conditions (*see* Annex C). These include cooling capacity, power input and ISEER.

6.5.2 100 percent load refers to the full rated capacity as defined by the standard rating conditions given in Table 1.

For continuously variable unloading machine's part load data shall be provided at a minimum of 75 percent, 50 percent, and 25 percent or to the minimum load point.

6.5.3 For discrete step unloading machines, part load rating data shall be provided at each stage of capacity.

6.5.4 Method of representing part load performance as a single value shall be as described in Annex C. The corresponding part load rating data required in order to calculate this single value also shall be reported as described in Annex C.

In cases where this value is declared by the manufacturer, all part load rating data necessary for its calculation shall also be published.

NOTE — Typical examples to calculate the rating tolerance and COP are described in Annex D.

6.6 Rating at Elevated Temperature (39 ºC)

See **16**.

7 TOLERANCES ON PERFORMANCE

7.1 The tolerance cooling capacity and COP shall be as per Table 2.

7.2 Ratings published and claimed to be in compliance with this standard shall be as specified in **6.2** to **6.4**.

7.2.2 Water pressure drop in the evaporator or condenser shall not exceed 115 percent of the rated pressure drop or rated pressure plus 600 mm to 610 mm water column drop whichever is higher at the specified water flow rate at any rated condition.

NOTE — The pressure drop measurement shall be as described in Annex G.

Table 2 Tolerances

(*Clauses* 7.1, 15.2 *and* 16)

Sl No.	Ratings	Related Tolerance Calculation
(1)	(2)	(3)
i)	Cooling capacity (full load)	Full load minimum: 100 % − Tol_1
ii)	COP (full load and part load)	Minimum of (rated COP)/(100% + Tol_1)
iii)	ISEER (*see* Annex C)	Minimum of (rated COP)/(100% + Tol_2)

where

$$Tol_1 = 10.5 - (0.07 \times \%load) + \left(\frac{833.3}{\Delta T_{\text{FL}}.\%load}\right)$$

$\% load$ = percent load;

ΔT_{FL} = difference between entering and leaving chilled water temperature at full-load in °C; and

$$Tol_2 = 0.065 + \frac{0.194}{\Delta T_{FL}}$$

NOTES

1 Tolerance for part load capacity shall be ± 2 percent. The ± 2.0 percent tolerance shall be calculated as 2.0 percent of the full load rated capacity (kW). For example, a nominal 50.0 percent part load point shall be tested between 48.0 percent and 52.0 percent of the full load capacity.

2 Typical examples on calculation are given in Annex D for guidance only.

7.2.3 The pump head for units with integral pump(s) in the evaporator or condenser shall not be less than 85 percent of the rated pump head at the specified water flow rate at any rated condition.

8 TEST SETUP

8.1 Test Room for the Air Side

8.1.1 The size of the test room shall be so selected that any resistance to air flow at the air inlet and air outlet of the test unit is avoided. The air flow through the room shall not be capable of initiating any short circuit between these two openings. The ambient air velocity in the room shall not be greater than the mean velocity of air throughout the unit inlet. Unless otherwise stated by the manufacturer, the air inlet or air outlet of the test unit shall be at a distance not less than 1 m from the surfaces of the test room.

8.1.2 Any direct heat radiation by heating units installed in the test room onto the unit or onto the temperature measuring probes shall be avoided.

8.2 Installation and Connection of the Test Appliance

Before carrying out the test specified in this standard, the liquid chilling packages shall be installed and suitably connected with the test equipment following the manufacturers instruction using the recommended procedures and accessories supplied by the manufacturer as given in installation and operation manual of the manufacturer.

No alterations to the equipment under test shall be made except for the attachment of required test apparatus and instruments in the prescribed manner.

When the water pump is an integral part of the unit and the external head pressure setting possible, the setting shall be made in order to reduce this external head pressure to approach zero.

For unit with open-type compressor, the electric motor shall be supplied as specified by the manufacturer. The compressor shall be operated at the rotational speed specified by the manufacturer.

If the manufacturer instruction indicates value for the temperature to be set on the control device for a given rating condition, then this value shall be used.

NOTE — If skilled personnel with knowledge of control software are required for the start of the system, the manufacturer or the nominated agent should be available when the system is being installed and prepared for tests.

8.3 Heat Transfer Surfaces

All heat transfer surfaces of evaporator and condenser shall be assumed to have fouling allowances of 0.000 m^2. °C/kW during the test. Tests conducted in accordance with this standard may require cleaning (in accordance with manufacturer’s instructions) of the heat transfer surfaces.

9 MEASURMENT DEVICES

9.1 Temperature and Pressure Measurement

Temperature and pressure measuring points shall be properly arranged in order to obtain mean values. The accuracy and precision of the measuring instruments including read-out devices for temperature measurements shall be as specified in Table 3.

To ensure adequate air distribution, thorough mixing, and uniform air temperature, the test room set up shall be properly designed and operated. The test room conditioning equipment airflow should be set such that recirculation of condenser discharged air is avoided. The recirculation of the condenser discharged air back into the condenser coil(s) shall be verified by method described below.

Multiple thermocouples (at least one per sampling tree location) shall be installed around the unit air discharge perimeter so that they are below the plane of condenser fan exhaust and just above the top of the condenser coil(s). The temperature difference indicated by these thermocouples shall not be greater than 5.0 °C from the average inlet air. Air distribution at the test facility point of supply to the unit shall be verified prior to beginning of the test and shall be adjusted if required. Mixing fans can also be used to ensure adequate air distribution in the test room. The mixing fans shall be placed such that the air from fans is in a direction away from air intake to the condenser and mixing fan exhaust direction is at an angle between 90° to 270° to the air entrance to the condenser air inlet. Necessary precaution shall be taken to ensure that no recirculation of condenser fan exhausts air are back through the test unit.

Adequate air distribution and control of air temperature is ensured provide the measured values are well within the permissible variation specified in Table 4. Annex E provides the check list for verification of air flow and temperature distribution. The verification shall be done before starting of any new test.

9.2 Air Sampling Device

Air sampling device is an air sampling tube assembly that draws air through sampling tubes in a manner to provide a uniform sampling of air entering the air-cooled condenser coil.

The air sampling device is designed to draw an uniform sample of the airflow entering the air-cooled condenser section for measurement of air temperature. A typical configuration for the sampling device is shown in Fig. 1 for a device with overall dimensions of 1.2 m × 1.2 m. Other dimension and rectangular shapes may be used provided the aspect ratio (width to height) of at least 2 to 1 is maintained. The material of air sampling device shall be stainless steel, plastic, or other suitable strong and durable materials. It shall have a main flow trunk tube with a series of branch tubes connected to the trunk tube having 10 to 20 branch tubes. The branch tubes shall have appropriately spaced holes and sized accordingly to provide equal airflow through all the holes by increasing the hole size which is further from the trunk tube to account for the static pressure regain effect in the branch and trunk tubes.

The number of sampling holes shall be greater than 50. The average minimum velocity through the sampling tree holes shall 0.75 m/s as determined by evaluating the sum of the open area of the holes as compared to the flow area in the aspirating psychrometer. The assembly shall have a tubular connection to allow a flexible tube to be connected to the sampling device and to the aspirating psychrometer.

The sampling device shall also be equipped with a thermocouple and thermopile grid to measure the average temperature of the airflow over the sampling device. The thermopile shall have at least 16 junction points per sampling device, evenly spaced across the sampling device, and connected in a parallel wiring circuit. On smaller units with only two sampling devices, it is acceptable to individually measure the 16 thermocouple points as a determination of room stratification. The air sampling devices shall be placed within 150 mm to 300 mm of the unit to minimize the risk of damage to the unit while ensuring that the air sampling tubes are measuring the air going into the test unit rather than the room air around the unit.

NOTE — The 15 mm × 25 mm slots shown in Fig. 1 are cut into the branches of the sampling device and are located inside of the trunk of the sampling device. They are placed to allow air to be pulled into the main trunk from each of the branches.

9.3 Aspirating Psychrometer

Aspirating psychrometer is a piece of equipment with a monitored airflow section that draws a uniform airflow velocity through the measurement section which has probes for measurement of air temperature:

a) It consists of a flow section and a fan to draw air through the flow section and measures an average value of the sampled air stream from air sampling device;
b) The flow section shall be equipped with two dry-bulb temperature probe connections, one of which shall be used for the facility temperature measurement and one of which shall be available to confirm this measurement using an additional or a reference validation temperature sensor probe;
c) The psychrometer shall include a fan that can be adjusted manually or automatically to maintain average velocity across the temperature sensors. A typical configuration for the aspirating psychrometer is shown in Fig. 2; and
d) The distance between the sensor probe and the fan shall be such that there is no abnormal impact of air velocity from the fan on the sensor probe.

10 MEASUREMENTS

10.1 Test Set Up Configuration

The dry-bulb temperature shall be measured at multiple locations entering the condenser, based on the airflow nominal face area at the point of measurement. Multiple temperature measurements shall be used to determine acceptable air distribution and the mean air temperature.

The use of air sampling device as a measuring station reduces the time required to setup a test and allows an additional or a reference validation temperature sensor(s) probe for redundant dry-bulb temperatures.

The nominal face area may extend beyond the condenser coil depending on coil configuration and orientation, and must include all regions through which air enters the unit. The nominal face area of the airflow shall be divided into a number of equal area sampling rectangles with aspect ratios no greater than 2 to 1. Each rectangular area shall have one air sampling device.

A minimum of one aspirating psychrometer per side of a chiller shall have to be used. For units with three sides, two sampling aspirating psychrometers shall have to be used but will require a separate air sampler device for the third side.

A minimum of two air sampling device should be used in any case, in order to assess air temperature uniformity.

The air sampling device shall be located such that it is at geometric centre of each rectangle condenser coil; either horizontal or vertical orientation of the branches is acceptable. The sampling device shall cover at least 80 percent of the height and 60 percent of the width of the air entrance to the unit (for long horizontal coils), or shall cover at least 80 percent of the width and 60 percent of the height of the air entrance (for tall vertical coils). The sampling device shall not extend beyond the face of the air entrance area. It is acceptable to block all branch inlet holes that extend beyond the face of the unit.

Fig. 3 gives examples of how an increasing number of air sampling devices are required for longer condenser coils.

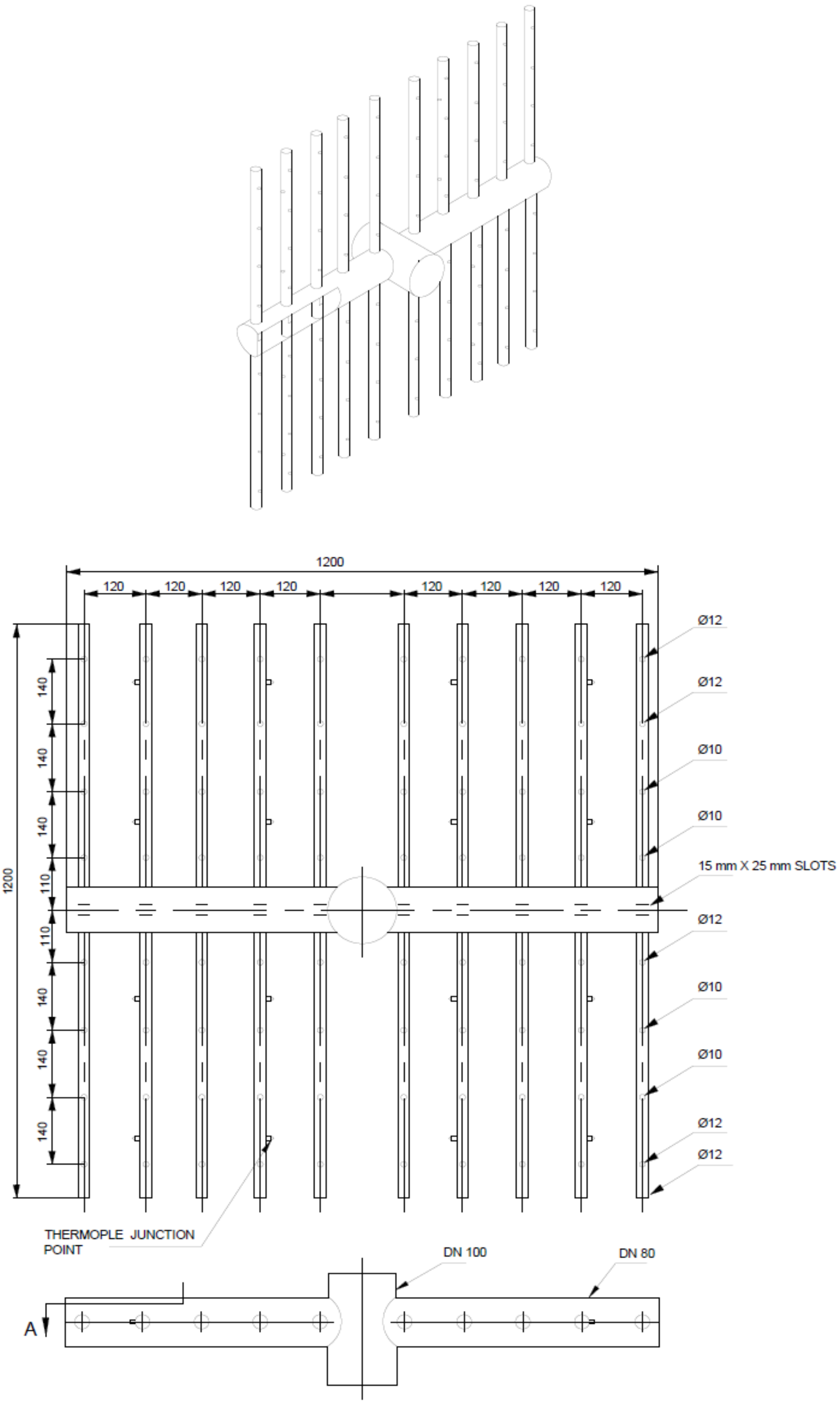

FIG. 1 TYPICAL AIR SAMPLING DEVICE

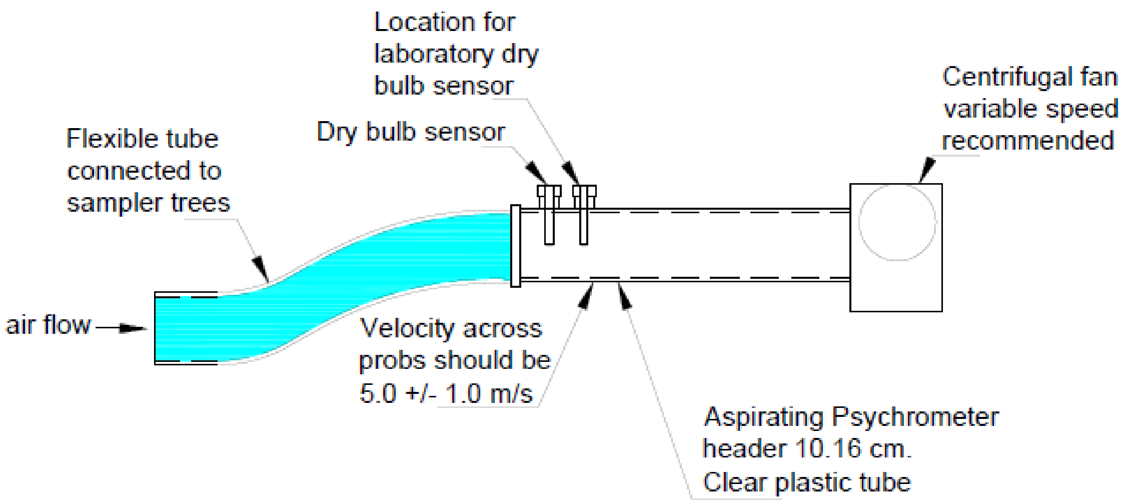
Location for laboratory dry bulb sensor
Centrifugal fan variable speed recommended
Flexible tube connected to sampler trees
Dry bulb sensor
air flow
Velocity across probs should be 5.0 +/- 1.0 m/s
Aspirating Psychrometer header 10.16 cm.
Clear plastic tube

FIG. 2 TYPICAL ASPIRATING PSYCHROMETER

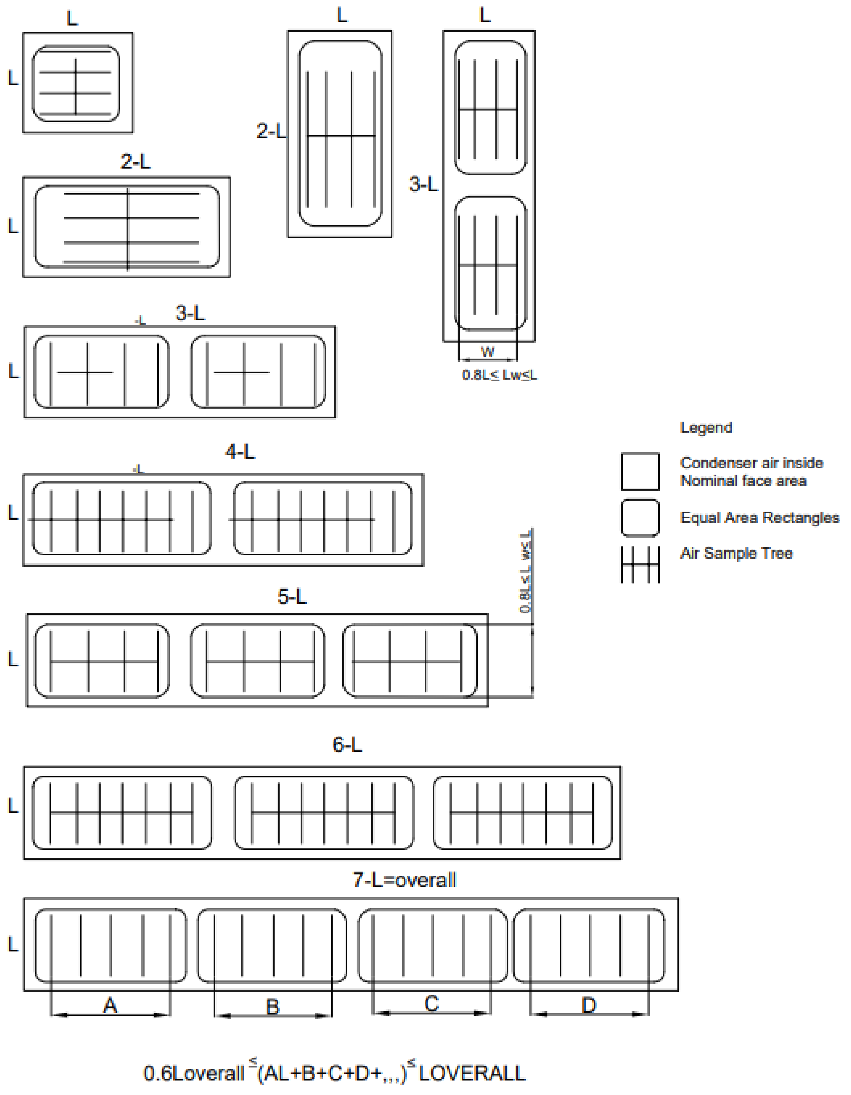

FIG. 3 DETERMINATION OF MEASUREMENT RECTANGLES AND REQUIRED NUMBER OF AIR SAMPLER TREES

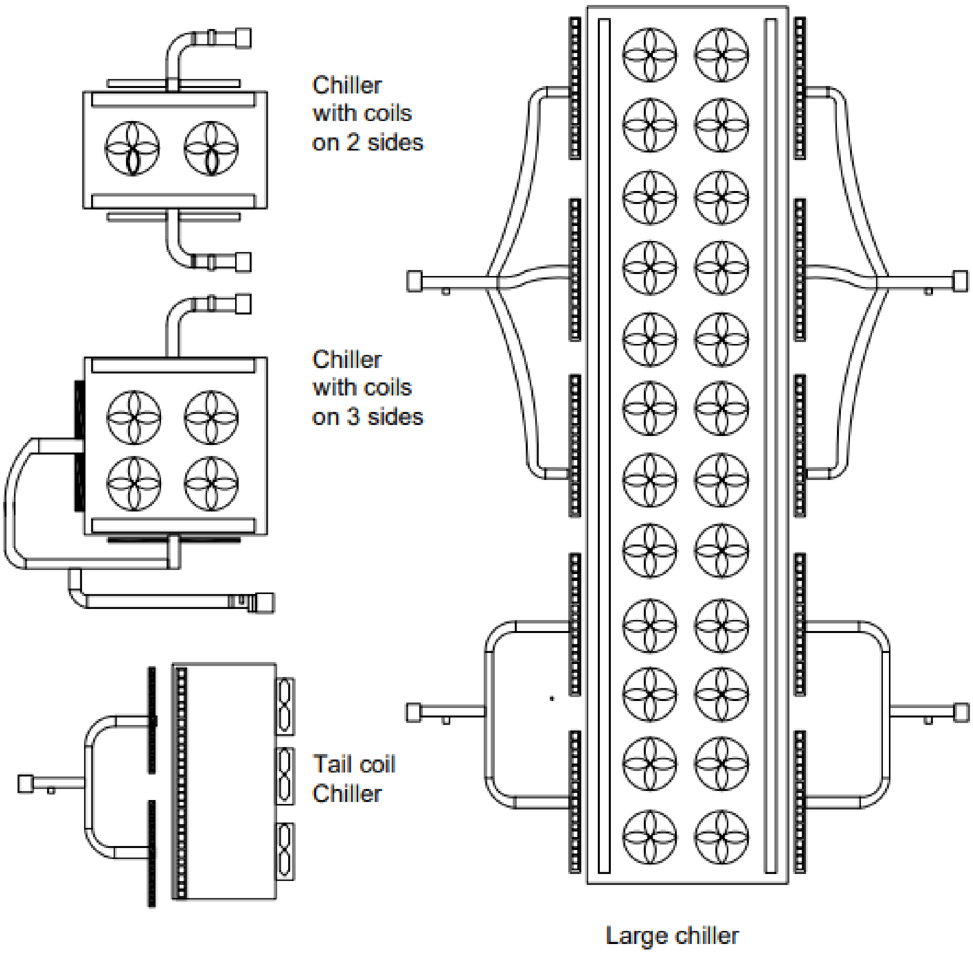

FIG. 4 TYPICAL TEST SETUP CONFIGURATIONS

A maximum of four sampling devices shall be connected to each aspirating psychrometer. The sampling device should be connected and routed to the aspirating psychrometer using insulated flexible tubing so that heat transfer to the air stream is prevented. In order to proportionately divide the flow stream for multiple sampling devices for a given aspirating psychrometer, the flexible tubing shall be of equal lengths for each sampling device.

Fig. 4 gives some typical examples of air sampling device and aspirating psychrometer setups.

Suitable measures shall be taken to ensure that the water temperatures are the average bulk stream temperatures. This shall include provisions for mixing of the fluid.

10.2 Integral Pumps

For liquid chilling packages with integral and adjustable water pumps, the pressure head, and temperature difference shall be set simultaneously.

10.2.1 *Units with Integral Pumps*

Units that include an integral evaporator fluid pump, and a condenser fluid pump shall have to be tested for both test condition A and test condition B as defined in **10.2.1.1** and **10.2.1.2**.

10.2.1.1 *Test condition A — Integral water pumps operating*

The unit shall be run with the integral pumps running and the external loop resistance of the test facility adjusted to obtain the desired rating fluid flow rates. The following values shall then be measured:

a) Evaporator and/or condenser entering and leaving water temperatures, °C;
b) Evaporator water flow rates, m^3/s;
c) Evaporator water static pressure, kPa; and
d) Total power input to the unit (compressor + pumps + controls), kW.

The calculated test capacities for this test will represent the cooling capacity and condenser heat rejection.

10.2.2.2 *Test condition B — Water pumps turned off*

A second test shall be run with the integral pumps turned off. The following values shall be measured:

a) Evaporator and condenser entering and leaving water temperatures, °C;

b) Evaporator and condenser water flow rates, m^3/s; and

c) Total power input to the unit (compressor + controls), kW.

The calculated test capacities for this test will represent the cooling capacity and condenser heat rejection.

Fig. 5 and Fig. 6 represent a typical arrangements of test facility and measurement locations for the test conditions A and B, respectively.

11 COOLING CAPACITY CALCULATION

11.1 Cooling Capacity (q_{ev})

It is determined from the measurement of the volume flow (Q) of the chilled liquid and the entering and leaving temperatures at the evaporator side, taking into consideration the specific heat capacity (c_p) and density (ρ) of the liquid.

The cooling capacity shall be determined using the following equation:

$$q_{ev} = (Q.\ \rho.\ c_p.\ \Delta T)/1\ 000 \qquad ...(1)$$

where

q_{ev} = cooling capacity, kW;
Q = volume flow rate, m^3/s;
ρ = fluid density, kg/m^3;
c_p = specific heat at constant pressure, J/kg.°C; and
ΔT = difference between entering and leaving liquid temperatures, °C.

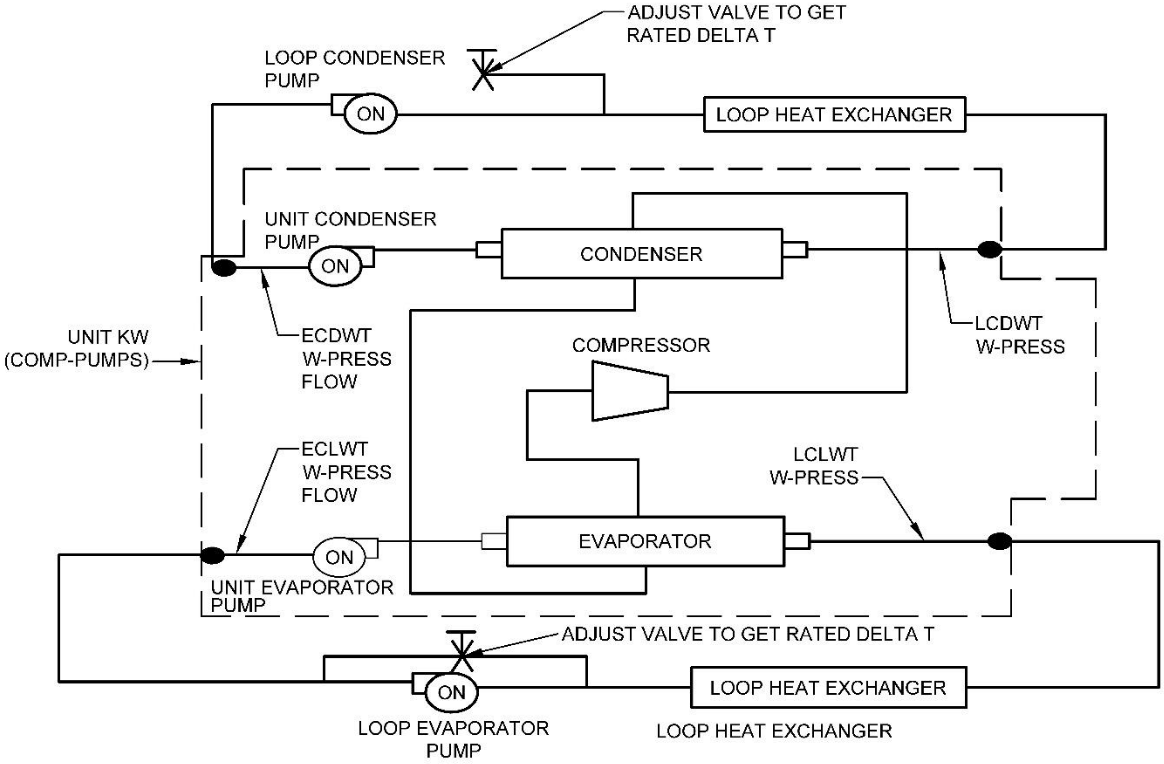

FIG. 5 TEST A CONFIGURATION — UNIT UNDER TEST WITH INTEGRAL LIQUID PUMPS ON

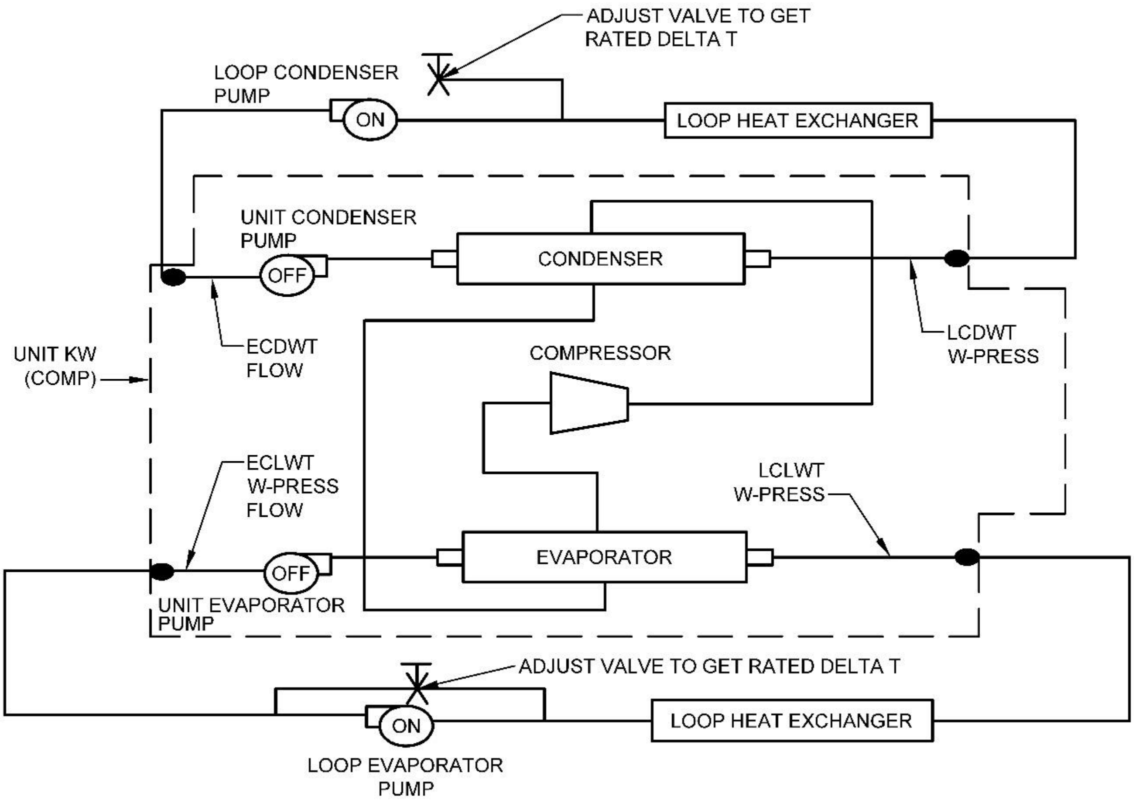

FIG. 6 TEST B CONFIGURATION — UNIT UNDER TEST WITH INTEGRAL LIQUID PUMPS OFF

11.2 Water-Cooled Condenser Heat Rejection (q_{cd})

It is determined from the volume flow of the water and the entering and leaving temperatures at the condenser, taking into consideration the specific heat capacity and density of the heat transfer medium.

The heat rejection capacity shall be determined using the following equation:

$$q_{cd} = (Q.\ \rho.\ c_p.\ \Delta T)/1\ 000 \qquad ...(2)$$

where

q_{cd} = heat rejection capacity, kW;
Q = volume flow rate, m^3/sec ;
ρ = density, kg/m^3;
c_p = specific heat at constant pressure, J/kg.°C; and
ΔT = difference between inlet and outlet temperatures, °C.

Heat balance method as given in **12** shall be used for water-cooled condensers.

12 HEAT BALANCE SUBSTANTIATING TEST

12.1 *Calculation of the Heat Balance*

Heat losses or gains through radiation, convection, bearing friction, oil cooler, etc, in most cases is negligible and hence are not be considered in the overall heat balance.

By omitting the effects of the negligible heat losses and gains mentioned above, the general heat balance equation shall be as follows:

$$q_{cd} = q_{ev} + W_{input} \qquad ...(3)$$

where

q_{cd} = heat rejection capacity;
q_{ev} = cooling capacity; and
W_{input} = compressor work input as defined in **12.2** and **12.3**.

12.2 In a hermetic package, where the compressor motor is cooled by refrigerant, chilled liquid or condenser water, the motor cooling load shall be included in the measured condenser load.

12.3 In packages using an open-type compressor with prime mover and external gear drive:

$$W_{input} = q_{prime\ mover} - q_{gear} \qquad ...(4)$$

where

W_{input} = power input to the compressor shaft, expressed, in kW;
$q_{prime\ mover}$ = power delivered by prime mover, expressed, in kW; and
q_{gear} = friction loss in gear box, expressed, in kW.

The value of $q_{\text{prime mover}}$ shall be determined from the power input to prime mover using certified data from the prime mover manufacturer.

The value of q_{gear} shall be determined from certified gear losses provided by the gear manufacturer.

12.4 Percent Heat Balance

Heat balance, in percent, is defined as:

$$\frac{(q_{ev} + W_{input}) - (q_{cd})}{(q_{cd})} \times 100 \qquad \text{...(5)}$$

The heat balance (percent) shall be within the tolerance calculated as per **12.5** for the applicable conditions for any test of a liquid chilling packages unit to be acceptable.

12.5 Verification Test Tolerance on Heat Balance

The verification test tolerance shall be determined from the following equation :

$$Tolerance = 10.5 - (0.07 \times \%Load) + \frac{833.3}{\Delta T_{FL} \times \%Load} \qquad \text{...(6)}$$

where

$\% Load$ = percent load;

FL = load factor; and

ΔT_{FL} = difference between entering and leaving chilled water temperature at full-load, ºC.

13 INSTRUMENTATIONS

13.1 Measurement Accuracy

The permissible variation in measurement shall not exceed the values specified in Table 3.

14 TEST PROCEDURE FOR COOLING CAPACITY AND POWER CONSUMPTION TEST

14.1 Steady State Conditions

Steady state condition is considered obtained and maintained when all the measured test parameters remain constant without having to alter the set values, for a minimum duration of 15 min, with respect to the tolerances given in Table 4. Periodic fluctuations of measured test parameters caused by the operation of regulation and control devices are permissible. However, the mean value of such fluctuations shall not exceed the permissible deviations listed in Table 4.

Table 3 Measurement Accuracy

(*Clauses* 9.1 *and* 13.1)

Sl No. (1)	Measurement (2)	Measurement System Accuracy (3)	Display Resolution (4)
i)	Water temperature, ˚C	± 0.11	0.01
ii)	Air temperature, ˚C	± 0.11	0.01
iii)	Differential pressure, kPa	± 1.0 % of reading	3 significant figures
iv)	Voltage		
	≤ 400V	± 1.0 % of full scale ± 2.0 % reading	4 significant figures (V, A, kW, Hz)
	> 400V	± 1.5 % of full scale ± 2.5 % of reading	
v)	Atmospheric pressure, kPa	± 1.0 kPa	0.1 kPa
vi)	Liquid mass flow rate, l/s	± 1.0 % of reading	4 significant figures
vii)	Volume flow, m^3/sec	± 1.0 of reading	0.1
viii)	Static pressure, Pa	± 5 Pa	0.1

NOTES

1 The cooling capacity shall be determined with a maximum uncertainty of 5 percent independent of the individual uncertainties of measurement including the uncertainties on the properties of fluids.

2 Current transformers (CTs) and potential transformers (PTs) shall have a metering accuracy class of 0.3 or better.

Table 4 Permissible Variation from Specified Value

(*Clause* 9.1, 14.1 *and* E-1)

Sl No.	Parameter	Permisible Variation of the Arithematic Mean Values from Specified Target Test Values	Permisible Variation of Individual Measured Values from Specified Target Test Values
(1)	(2)	(3)	(4)
i)	Water:		
	a) Entering temperature,° C	± 0.3	± 0.6
	b) Leaving temperature,° C	± 0.3	± 0.6
	c) Volume flow, m^3/sec	± 5 %	± 10 %
	d) Static pressure difference, kPa	Maximum of 1.15 times rated static pressure drop or rated static pressure drop plus 600 mm to 610 mm of water column, whichever is higher	
ii)	Air: dry bulb temperature, °C	± 0.6	± 1
iii)	Voltage:		
	a) Single phase, V	± 2 %	± 5 %
	b) Three phase, V	± 5 %	± 10 %
	c) Frequency, Hz	± 1 %	± 2 %

14.2 Output Measurement of Cooling Capacity

For the output measurement it is necessary to record all the necessary data continuously. In the case of recording instruments which operate on a cyclic basis, the sequence shall be adjusted such that a complete recording is monitored at least once every 30 s.

The output shall be measured in the steady state condition recording 4 sets of reading at every 5 min interval.

14.3 Calculation of Test Results

14.3.1 *Cooling Capacity*

Cooling capacity shall be determined from the average of the capacities calculated from the four sets of data collected as described in **14.2**.

14.3.2 *Power Consumption*

The power consumption for the complete unit and the auxiliaries shall be measured as per the procedure given below:

a) For test units with a frequency conversion device or motor starter supplied as part of the circuit, the unit power input shall be measured at the input terminals of the frequency converter or motor starter. For liquid chilling package units for testing not supplied with the starter or frequency converter, a starter or frequency converter of similar type shall be used for the test;

b) Power consumed by auxiliaries, during normal operation of the package shall be included in the total power consumption for test units which are supplied as part of the unit;

c) In case of open-type compressors, where the motor and/or gear set is not supplied by the manufacturer, or for the compressor, shaft input shall be determined as stated in **12.3** or **12.4**; and

d) In case of air-cooled condensers, the power consumption of condenser fan shall be included in the total power consumption of the package.

14.4 Data to be Recorded

14.4.1 *Measurement Data*

The data to be recorded for the capacity tests are as described in Table 5. The table provides the general information required but is not intended to limit the data to be obtained.

Table 5 Data to be Recorded

(*Clause* 17.4.1)

Sl No.	**Measured Quantity or Result**	**Liquid-Cooled Condenser**	**Air-Cooled Condenser**
(1)	(2)	(3)	(4)
i)	Ambient conditions:		
	a) Air temperature, dry bulb, °C	–	√
	b) Atmospheric pressure, kPa	√	√
ii)	Electrical quantities:		
	a) Voltage, V	√	√
	b) Total power input, W (*see* **3.14**)	√	√
	c) Frequency, Hz	√	√
iii)	Chilled liquid:		
	a) Inlet temperature,°C	√	√
	b) Outlet temperature,°C	√	√
	c) Volume flow, m^3/s	√	√
	d) Pressure drop/ESP, kPa	√	√
	e) Concentration, % (for fluids other than water)	√	√
iv)	Condenser liquid:		
	a) Inlet temperature, °C	√	–
	b) Outlet temperature, °C	√	–
	c) Volume flow, m^3/s	√	–
	d) Pressure drop/ESP, kPa	√	–
v)	Air:		
	a) Dry bulb inlet temperature, °C	–	√
vi)	Refrigerant:		
	a) Refrigerant charge, kg (if adjusted)	√	√
vii)	Heat balance, percentage	√	–
viii)	Cooling capacity, kW	√	√
ix)	COP, kW/kW	√	√

14.4.2 *Supplementary Data to be Recorded for General Information*

Following additional information shall also be recorded and reported along with test report:

a) Nameplate data which includes but not limited to make, model, size and type of refrigerant, sufficient to completely identify the water chiller;

b) For units with open-type compressors where motor and or gear set are not supplied by manufacturer, or for engine or turbine drives, record compressor driver or input rotational speed;

c) Wherever applicable, motor nameplate data; and

d) Date, place, and time of test.

15 COMPLIANCE

15.1 The measured cooling capacity at full load (100 percent) shall not be less than 10 percent of the value declared by the manufacturer on the rating plate. For power consumption it shall not be more than 10 percent of the value declared by the manufacturer on the rating plate.

15.2 Refer Table 2 for tolerance on COP and ISEER.

16 COOLING CAPACITY AT ELEVATED TEMPERATURE (FOR AIR COOLED CONDENSER ONLY)

Capacity of air-cooled chiller measured at 39 °C at full capacity (100 percent load) at the standard rating conditions shall be declared and reported in the test report by the manufacturer. Tolerance on cooling capacity measured value specified in Table 2 shall apply for the measurement.

NOTE — The purpose of the test is to give the buyer a prior information about the performance of the chiller at higher temperature.

This capacity at 39 °C shall be determined by testing or through software. The software shall be validated by the appropriate authority. Declaration of cooling capacity and power consumption at 39 °C shall be through software output or catalogue.

17 Sound Pressure Measurement Test

17.1 The sound pressure measurement shall be done at rated condition specified in Table 1. In case, if the conditions as per Table 1 cannot be maintained, the sound pressure measurement shall be done at possible temperature conditions and data shall be reported in the test report. The measurement shall be done in accordance with either ISO 9614-1, ISO 9614-2, ISO 3747, or ISO 3744 for unit under free field condition.

17.1.2 For sound pressure measurement test, the following conditions shall be used:

a) Test unit shall be set to operate at full load in cooling mode;
b) With the pump operating for units with integral pump; and
c) All fans in running mode for air-cooled chiller.

17.1.3 The sound level shall be as declared by the manufacture and shall not exceed more than 3 dB from the declared value.

18 TESTS

18.1 Type Test

Following tests shall constitute type tests:

a) Leakage current tests as per **13.2** of IS 302 (Part 1);
b) Electric strength (HV) as per **13.3** of IS 302 (Part 1);
c) Protection against electric shock as per **8** of IS 302 (Part 1); and
d) Provision for earthing as per **27** of IS 302 (Part 1).

18.2 Routine Test

Following tests shall constitute routine tests:

a) Earthing continuity test as per **A-1** of IS 302 (Part 1); and
b) Electric Strength (HV) as per **A-2** of IS 302 (Part 1).

19 MARKING

19.1 A name plate of corrosion-resistant material shall be affixed on the chiller with the following details:

a) Manufacturer’s name and address, and country of manufacture;
b) Model number designation;
c) Serial number;
d) Refrigerant designation (in accordance with IS 16656/ISO 817);
e) Rated voltage, phase, and frequency;
f) Published total power input, kW;
g) Maximum starting current, Amperes; and
h) Refrigerant charge, kg.
j) Full load cooling capacity at standard rated condition (kW) (standard rating condition defined in Table 1)

19.2 The markings required by the standard shall be clearly legible and durable. Compliance is checked by inspection and by rubbing the marking by hand for 15 s with a piece of cloth soaked with water and again for 15 s with a piece of cloth soaked with petroleum spirit. The petroleum spirit to be used for the test is aliphatic solvent hexane. After the test, the markings shall be clearly legible. It shall not be possible to remove marking plates nor shall they show curling.

NOTE — In considering the durability of the marking, the effect of normal use is taken into account. For example, marking by means of paint or enamel, other than vitreous enamel, on containers that are likely to be cleaned frequently, is not considered to be durable.

19.3 BIS Certification Marking

The liquid chilling package may also be marked with the Standard Mark.

The product(s) conforming to the requirements of this standard may be certified as per the conformity assessment schemes under the provisions of the *Bureau of Indian Standards Act*, 2016 and the Rules and Regulations framed thereunder, and the products may be marked with the Standard Mark.

20 INSTRUCTION MANUAL

The information provided in (a) to (g) shall be furnished in the product/instruction manual by the manufacturer with every packaged unit sold.

a) The liquid chilling package manufacturer has to submit the dimensional drawing with point loads including the structural supporting system designed for installation;

b) Liquid chilling package manufacturer shall provide suitable instructions on the minimum spacing required for the air movement around the chillers and the suggested maintenance space including access to the liquid chilling package unit yard;

c) The liquid chilling package manufacturer shall provide shipping weight of the unit, recommended handling and transportation method(s) including transportation from manufacturer location to the installation location;

d) Commissioning of the liquid chilling package shall be done by qualified personnel as recommended by the manufacturer or accredited training organization. The qualified commissioning personnel shall test and provide the test data to the customer containing relevant electrical and refrigerant parameters for assessing the performance of the liquid chilling package;

e) Commissioning personnel shall train representative of the customer/user of the liquid chilling package on operation and routine maintenance;

f) Liquid chilling package manufacturer shall provide the complete details to the customer/user, for example dimensions and any additional information as requested by customer; and

g) Liquid chilling package manufacturer shall suggest the quality of water in the closed loop evaporator and open loop condenser and the suggested make up water quality.

ANNEX A

(*Clause* 2)

LIST OF REFERRED STANDARDS

IS No./Other Standards	*Title*
IS 302 (Part 1) : 2008	Safety of household and similar electrical appliances: Part 1 General requirements (*sixth revision*)
IS 3615 : 2020	Glossary of terms used in refrigeration and air conditioning (*second revision*)
IS 15575 (Part 1) : 2016/IEC 61672-1 : 2013	Electroacoustics — Sound level meters: Part 1 Specifications (*first revision*)
IS 16656 : 2017/ ISO 817 : 2014	Refrigerants — Designation and safety classification
ISO 3744 : 2010	Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Engineering methods for an essentially free field over a reflecting plane
ISO 3747 : 2010	Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Engineering/survey methods for use in situ in a reverberant environment
ISO 9614-1 : 1993	Acoustics — Determination of sound power levels of noise sources using sound intensity — Part 1: Measurement at discrete points
ISO 9614-2 : 1996	Acoustics — Determination of sound power levels of noise sources using sound intensity — Part 2: Measurement by scanning

ANNEX B

(*Clause* 6.2)

METHOD FOR SIMULATING FOULING FACTOR ALLOWANCE

B-1 PURPOSE

B-1.1 For all rated condition testing, evaporator water-side and condenser water-side or air-side heat transfer surfaces shall be considered clean during testing. Tests will be assumed to reflect fouling factors of 0.000 $m^2.°C/kW$. To determine the capacity of the chiller package at the nominal fouling conditions, the procedure given in this annex shall be used to determine an adjustment for the evaporator and or condenser water temperatures.

B-1.2 This annex describes the method for adjusting the operating conditions of a test unit to simulate the required rating water side fouling allowance.

It is assumed that all heat transfer surfaces have a fouling allowance of 0.000 0 $m^2.°C/kW$ during the test. The procedure below defines a way to adjust the water-cooled condenser water temperatures and the evaporator water temperatures to simulate a desired field fouling allowance.

The procedure below is only applicable to the waterside of evaporators and condensers and excludes air-cooled condensers.

B-2 FOULING FACTOR ALLOWANCE PROCEDURE

B-2.1 Obtain the log mean temperature difference (*LMTD*) for the evaporator and/or condenser using the following equation at the specified field fouling factor allowance (*ff*).

$$LMTD = \frac{R}{ln\left(1+\frac{R}{S}\right)} \qquad \ldots(7)$$

where

R = water temperature range = absolute value ($t_{wl} - t_{we}$), °C; and

S = small temperature difference:

= absolute value ($t_{scd} - t_{wl}$), °C, for condenser, and

= absolute value ($t_{sev} - t_{wl}$), °C, for evaporator.

B-2.2 Derivation of LMTD

The incremental *LMTD (ILMTD)* is determined using the following equation:

$$ILMTD = ff\left(\frac{q}{A}\right) \qquad \ldots(8)$$

Note that *A* (area) is the surface area on the water side.

B-2.3 The water temperature difference TD_a needed to simulate the additional fouling, TD_a, can now be calculated as follows:

$$TD_a = S - S_c \qquad \ldots(9)$$

$$TD_a = S - \frac{R}{e^{z}-1} \qquad \ldots(10)$$

where

$$Z = \frac{R}{LMTD-ILMTD} \qquad \ldots(11)$$

$$S_c = \frac{R}{e^{z}-1} \qquad \ldots(12)$$

S_c = small temperature difference as tested in clean condition.

The water temperature difference, TD_a, is then added to the condenser entering water temperature or subtracted from the evaporator leaving water temperature to simulate the additional fouling factor.

B-3 EXAMPLE — CONDENSER FOULING

Fouling factor allowance, ff = 0.088 m^2.°C/kW

Condenser load, q = 850 kW

Condenser leaving water temp, T_{wl} = 35 °C

Condenser entering water temp, T_{we} = 28 °C

Water surface area, A = 50 m^2

Saturated condensing temperature, t_{scd} = 40 °C

$$S = t_{scd} - t_{wl} = 40 - 35 = 5\ °C$$

$$R = t_{wl} - t_{we} = 35 - 28 = 7\ °C$$

$$Z = \frac{R}{LMTD-ILMTD} = \frac{7}{7.966-0.748} = 0.97$$

$$TD_a = S - \frac{R}{e^{z}-1} = 5.0 - \frac{7.0}{e^{0.97}-1} = 0.7\ °C$$

The entering condenser water temperature for testing is then raised 0.7 °C to simulate the fouling factor allowance of 0.088 m^2.°C/kW. The entering condenser water temperature will be (28 + 0.7) °C or 28.7 °C.

B-4 SYMBOLS AND SUBSCRIPTS

The symbols and subscripts used in equations (1) to (6) are as follows:

a) Symbols:

A = water heat transfer surface, m^2, for evaporator or condenser

e = base of natural logarithm

ff = fouling factor allowance, m^2.°C/kW

q = capacity, kW

R = water temperature range

S = small temperature difference

t = temperature, °C

t_{scd} = saturated vapor temperature entering the condenser for single component or azeotrope refrigerants and equal dew point for zeotropic refrigerants (at compressor discharge pressure)

t_{sev} = saturated vapor temperature leaving the evaporator for single component or azeotrope refrigerants and average dew point for zeotropic refrigerants (at compressor average suction pressure)

b) Subscripts:

a = additional fouling

c = cleaned

cd = condenser

e = entering (for example, t_{we} – water entering temperature)

ev = evaporator

f = fouled or fouling

l = leaving (for example, t_{wl} – water leaving temperature)

s = saturation

w = water

ANNEX C

(*Clauses* 6.5.1, 6.5.4 *and Table* 2)

INDIAN SEASONAL ENERGY EFFICIENCY RATIO (ISEER)

C-1 GENERAL

The annex defines a uniform procedure for the calculation of a single value number that is a representation of the part load efficiency of a chiller which is defined as Indian seasonal energy efficiency ratio or ISEER.

C-2 OBJECTIVE

The procedure laid in this annex is only for equipment covered under the scope of this standard. The ISEER equation and procedure are intended to be an average representation of a single chiller in ~~a~~ typical commercial installation with conventional operating parameters. The procedure is intended to provide a consistent uniform method for calculating the single number for part load operation. A fixed set of operating load points and conditions are defined to allow for equal comparison of products. But allowances have been made for regional values to be defined to allow for correlation to regional ambient and building operational and construction standards. The intent is that this single value metric be used by efficiency standards and certification programs around the world that require more than a full load efficiency level.

The equation has been derived to provide a representation of the average part load efficiency for a single chiller only. However, for operating cost and energy analysis it is best to use a comprehensive analysis tool that reflects the actual weather data, building load characteristics, operational hours, economizer capabilities and energy drawn by auxiliaries such as pumps and cooling towers when calculating the applied chiller system efficiency. This becomes increasingly important with multiple chiller systems because individual chillers operating within multiple chiller systems can have significantly different load profiles than a single chiller.

C-3 EQUATION AND DEFINITION OF TERMS

C-3.1 The single value part load rating shall be determined by using the following equation:

$$\text{ISEER} = A \times COP_{100\%} + B \times COP_{75\%} + C \times COP_{50\%} + D \times COP_{25\%} \qquad \text{...(13)}$$

where

$COP_{100\%}$ = *COP* at full load rating point;

$COP_{75\%}$ = *COP* at 75 percent load rating point;

$COP_{50\%}$ = *COP* at 50 percent load rating point;

$COP_{25\%}$ = *COP* at 25 percent load rating point;

A = weighting factor for 100 percent load;

B = weighting factor for 75 percent load;

C = weighting factor for 50 percent load; and

D = weighting factor for 25 percent load.

The values of *A*, *B*, *C* and *D* are based on the weighted average of the building types having similar type of occupancy heat load across all climatic zones of India. Values that have been developed are shown in Table 6.

Table 6 Weighting Coefficients A to D for Calculation of ISEER

(*Clause* C-3.1)

Sl No. (1)	Load Rate (%) (2)	Weighting Coefficients (3)
i)	100	A = 06
ii)	75	B = 48
iii)	50	C = 36
iv)	25	D = 10

The ISEER rating requires that the unit efficiency be determined at 100 percent, 75 percent, 50 percent and 25 percent at the conditions specified in Table 7.

Table 7 Indian Seasonal Energy Efficiency Rating Conditions

(*Clause* C-3.1)

Sl No.	Measurement Parameters	Water-Cooled	Air-Cooled
(1)	(2)	(3)	(4)
i)	Evaporator water temperature:		
	a) Leaving	7 °C	
	b) Flow	Flow rate equal to a 5 °C ΔT at 100 percent loading	
ii)	Evaporator fouling factor allowance		
	a) Water side	0.018 m^2.°C /kW	
iii)	Condenser fouling factor allowance		
	a) Water side	0.044 m^2.°C /kW	0.000 m^2.°C /kW
	b) Condenser flow	Flow rate equal to a 5 °C ΔT at 100 percent rating point	Airflow equal to the full load rating
iv)	Condenser entering temperature:		
	a) 100 percent load	30 °C	35 °C
	b) 75 percent load	26 °C	27 °C
	c) 50 percent load	23 °C	19 °C
	d) 25 percent load	20 °C	13 °C

For units with proportional unloading, performance should be obtained at the 25 percent, 50 percent, 75 percent, and 100 percent load to calculate the ISEER.

If the unit has discrete steps of unloading, but due to its capacity control logic cannot be operated at 75 percent, 50 percent, or 25 percent capacity, then the unit should be operated at other load points and the 75 percent, 50 percent, or 25 percent capacity efficiencies should be determined by interpolating between the two operating points that frame the rating point. The required condenser entering temperature at the requested load point should be used and a capacity test run at each unloading stage on either side of the desired part load rating point then should be interpolated to obtain the desired part load point rating. For example, if the unit has capacity stages at 33 percent and 66 percent nominal displacement, then the 50 percent point can be determined by obtaining the capacity and efficiency at the 66 percent unloading stage at 50 percent entering temperature and another test, at the 33 percent unloading stage at the 50 percent entering temperature. Extrapolation of data shall not be used and the desired rating point must be determined by two actual operating points. An actual chiller capacity load, equal to or less than the required loading point shall be used to plot the performance curve. For example, if the minimum actual capacity is 33 percent, then the curve can be used to determine the 50 percent capacity point, but not the 25 percent capacity point.

If a unit cannot be unloaded to the 25 percent, 50 percent, or 75 percent capacity point, then the unit should be run at the minimum step of unloading at the condenser entering temperature based on Table 8 for 25 percent, 50 percent, or 75 percent capacity points as required. The efficiency shall then be determined by using the following equation:

$$COP = \frac{\text{Capacity}_{Min}}{C_{\text{d}} \times \text{Power}_{Min}} \qquad \ldots(14)$$

where

Capacity$_{Min}$ and Power$_{Min}$ are the values from the lowest stage of unloading running at the desired part load rating point; and

C_d is a degradation factor to account for cycling of the compressor for capacities less than the minimum step of capacity.

C_{d} should be calculated using the following equation:

$$C_{\text{d}} = (-\,0.13 \times LF) + 1.13 \qquad \ldots(15)$$

The factor *LF* should be calculated using the following equation:

$$LF = \frac{\left(\frac{\%\text{Load}}{100}\right) \times (\text{Full load unit capacity})}{\text{Part load unit capacity}} \qquad \ldots(16)$$

where

Percent load = standard loading point that is 75 percent, 50 percent and 25 percent of full load.

Full load capacity is the capacity at the full load

100 percent rating point as defined in Table 8.

The part load capacity of the unit is the capacity obtained when the machine is run at its lowest stage of capacity at the desired load point rating conditions.

For water-cooled units where a unit has been selected for operating conditions that will not allow operation at the full load condenser entering fluid conditions, then an ISEER cannot be calculated. For these applications, ISEER can be determined, using the same procedures as defined above except that for the full load rating point the machine will be run at the maximum design entering condenser temperature. The 75 percent, 50 percent and 25 percent points will then be run at the temperatures defined in Table 8 unless the unit will not operate at these conditions and then the maximum option temperature shall be used. For example, if a chiller was selected for 30 °C full load condenser entering fluid temperature, then the 100 percent loading would be determined at a 30 °C entering conditions. For ISEER rating the 75 percent would then be determined at a 26 °C entering temperature, the 50 percent at 23 °C and the 25 percent point at 20 °C (*see* Table 7).

C-4 SAMPLE CALCULATION

Using the Table 8 data, the part load COP value can be calculated.

The following is an example of an ISEER calculation for an air-cooled machine with 3 discrete stages of capacity with an ISEER determined for the average profile.

The 75 percent load point is determined by interpolating between the 112 percent and 70 percent load point.

$$COP_{75\%} = \frac{(75\ -\ 70)}{(112\ -\ 70)} \times (3.85 - 4.35) + 4.35$$
$$= 4.29$$

The 50 percent load point is determined by interpolating between the 73 percent and 40 percent load points.

$$COP_{50\%} = \frac{(50 - 40)}{(73 - 40)} \times (4.45 - 4.59) + 4.59 = 4.54$$

Because the unit cannot unload to 25 percent capacity or less, the following additional calculations are required to determine the $COP_{25\%}$. Using the minimum capacity data point listed above, that was determined at the minimum step of capacity at the 20 °C ambient conditions the following calculations can be made.

$$LF = \frac{0.25\ \times 350}{146.9} = 0.60$$

$$C_d = (-\ 0.13 \times 0.60) + 1.13 = 1.05$$

$$COP = \frac{146.9}{1.05 \times 33.3} = 4.20$$

Using the *A*, *B*, *C* and *D* efficiencies the ISEER (COP) can then be calculated as follows:

ISEER (COP) = (0.06 × 3.79) + (0.48 × 4.29)
+ (0.36 × 4.54) + (0.10 × 4.20) = 4.34

Table 8 Chiller Part Load Values Data

(*Clauses* C-3 *and* C-4)

Sl No. (1)	**Rating** (%) (2)	**Step** (3)	**Capacity** (kW) (4)	**% Load** (5)	**Temp of Entering Air** (°C) (6)	**Input** (kW) (7)	**COP** (8)
i)	100	1(100 %)	350.0	100	35	92.3	3.79
ii)	75	1(100 %)	392.0	112	27	101.8	3.85
iii)	75	2(66 %)	245.0	70	27	56.3	4.35
iv)	50	2(66 %)	256.0	73	19	57.5	4.45
v)	50	3(33 %)	141.0	40	19	30.7	4.59
vi)	25	3(33 %)	146.9	42	13	33.3	4.41

C-5 APPROACH ADOPTED FOR ISEER COEFFICIENT CALCULATIONS

Following approach shall be adopted for ISEER coefficient calculations:

a) Weather data is taken from bin weather file used for energy simulation of buildings;

b) Following building types have been analyzed through simulation for studying the chiller load variation:

  1) Office building — large, 24 h use;
  2) Office building — large, daytime use;
  3) Office building — small, 24 h use;
  4) Office building — small, daytime use;
  5) Retail shopping building, daytime use;
  6) Hotel building, 24 h use; and
  7) Hospital, 24 h use.

c) Building envelopes, occupancy, light power density (LPD), environmental protection declaration (EPD) etc are the taken from recently built modern buildings;

d) Models of all seven types have been simulated for representative cities of various climatic zones: hot and dry, composite, warm and humid, and moderate;

e) Grouping of data as per bin method for computation of ISEER coefficients is done on the basis of load on chiller;

f) Bin group is selected in such a way that average of peak bin group should be 75 percent load and similarly average of low bin group and min bin group should be 50 percent and 25 percent load respectively; and

g) ISEER coefficients for 25 percent, 50 percent, 75 percent and 100 percent load are first computed separately for each building type in each representative city. Average of all the cases has led to the final set of ISEER coefficients.

Typical example for the calculation of ISEER for large office building is shown in Table 9.

Table 9 Calculation of ISEER for Large Office Building

(*Clause* C-5)

Sl No.	**Percentage Load**	**Average Percent Load**	**Number of Hours**	**kW-hr**	***Min* Bin**	**Low Bin**	**Peak Bin**	**Design Bin**
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i)	100 to 87.5	93.75	237	781.4	0	0	0	222.2
ii)	87.5 to 81.25	84.37	353	1 047.3	0	0	297.8	0.0
iii)	81.25 to 75	78.125	511	1 403.9	0	0	399.2	0
iv)	75 to 68.25	71.87	642	1 622.7	0	0	461.4	0
v)	68.25 to 62.5	65.625	718	1 657.1	0	0	471.2	0
vi)	62.5 to 56.25	59.375	1 360	2 839.9	0	807.5	0	0
vii)	56.25 to 50	53.125	1 404	2 623.2	0	745.9	0	0
viii)	50 to 43.75	46.875	1 411	2 326.0	0	661.4	0	0
ix)	43.75 to 37.5	40.625	846	1 208.7	0	343.7	0	0
x)	37.5 to 31.25	34.375	522	630.9	179.4	0	0	0
xi)	31.25 to 25	25.125	364	321.8	91.5	0	0	0
xii)	25 to 18.75	21.875	235	180.8	51.4	0	0	0
xiii)	18.75 to 12.5	15.625	116	63.7	18.1	0	0	0
xiv)	12.5 to 6.25	9.375	37	12.3	3.5	0	0	0
xv)	6.25 to 0	3.125	4	0.4	0.1	0	0	0
			8 760	16 720.2	344.0	2 558.5	1 629.6	222.2
				weightage	7.2 percent	53.8 percent	34.3 percent	4.7 percent
					D	C	B	A

ANNEX D

(*Clauses* 6.5.4 *and Table* 2)

SAMPLE CALCULATIONS FOR RATING TOLERNECES

D-1 PURPOSE

The purpose of this annex is to provide guidance for calculation of rating tolerance as described in **7**.

Following equation is used to calculate permissible tolerances on capacity (kW) and COP:

$$Tolerance(percentage) = 10.5 - (0.07\ \times \%load) + \left(\frac{833.3}{\Delta T_{FL} \times\ \%load}\right)$$

D-1.1 FULL-LOAD EXAMPLE IN COP

Rated capacity = 35 kW

Rated power input = 9.230 kW

Cooling, $\Delta\ T_{FL}$ = 5 K

$$COP = \frac{35}{9.230} = 3.79$$

$$Tolerance\ (percentage) = 10.50 - (0.07 \times 100) + \frac{833.3}{5 \times 100} = 10.5 - 7 + 1.66 = 5.16$$

$$Minimum\ allowable\ capacity = \frac{100 - 5.16}{100} \times 35 = 33.194\ kW$$

$$Minimum\ allowable\ COP = \frac{3.79}{100 + 5.16} \times 100 = 3.6$$

D-1.2 PART-LOAD EXAMPLE IN COP

Assume a part load of 69.5 % of the rated capacity.

Part load capacity = 24.325 kW

Part load power input = 5.960 kW

$\Delta\ T_{FL}$ = 5.0 °C

$$COP = \frac{24.325}{5.960} = 4.08$$

$$Tolerance\ (percentage) = 10.50 - (0.07 \times 69.5) + \frac{833.3}{5 \times 69.5} = 10.5 - 4.865 + 2.39 = 8.025$$

$$Minimum\ allowable\ COP = \frac{4.08}{100 + 8.025} \times 100 = 3.77$$

ANNEX E

(*Clause* 9.1)

AIR DISTRIBUTION CHECK PROCEDURE AND CHECK LIST

E-1 Following procedure shall be adopted for verification of the air and temperature distribution within the lab. This may be conducted at every test set up to verify the air and temperature distribution within the specified limits.

a) Set up the air sampler device and the aspirating psychrometer around the chiller condensing unit based on the unit configuration as shown in Fig. 4. Keep the aspirating psychrometer’s air mixing fan ON;
b) Ensure all the thermocouples mounted on the air sampler device measures same value and measures ambient. The measured values shall be within the allowable tolerance as per Table 4;
c) Start the chiller and conditioning equipment of the lab. Once the appropriate stable conditions have been achieved, record the temperature values as simultaneously as possible prior to start of data collection. Note the data in the table below;
d) Calculate the mean air dry-bulb temperature (MADBT);
e) Confirm that each of the aspirating psychrometer values are within ± 1°C (for units ≤ 703.4 kW or ± 1.7 °C (for units ≥ 703.4 kW) of MADBT;
f) Confirm that each thermocouple values are within ± 1 °C of each aspirating psychrometer;
g) Confirm each recirculating thermocouple values shall be within ± 2.7 °C of the MADBT; and
h) Note the values in a sketch (*see* Fig. 7) as shown below. The data shall be noted as shown in Fig. 8.

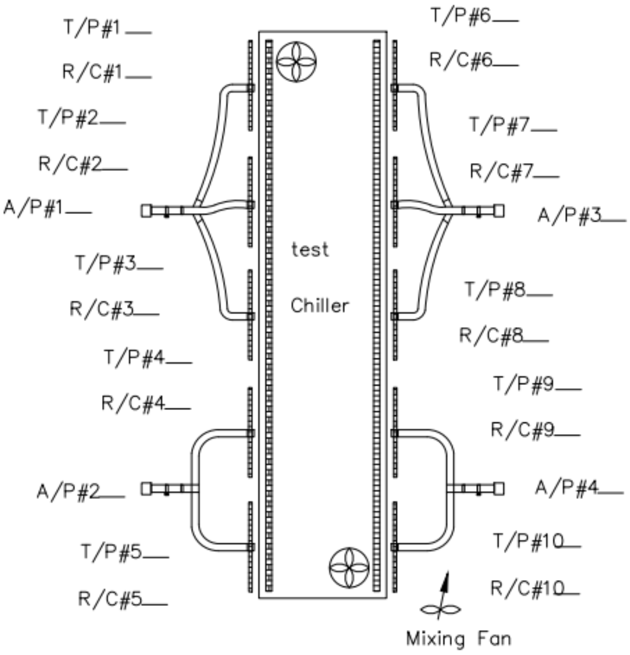

FIG. 7 SAMPLE SKETCH

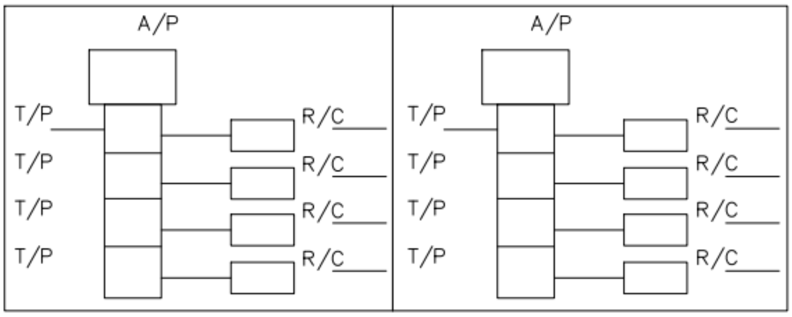

FIG. 8 DATA TO BE NOTED

ANNEX F

(*Clauses* 3.13 *and Table* 1)

BAROMETRIC PRESSURE ADJUSTMENT

F-1 PURPOSE

The purpose of this annex is to prescribe a method of adjusting measured test data according to the local barometric pressure.

F-2 BACKGROUND

In order to ensure that performance can be uniformly compared from one unit to another and from one manufacturer to another, performance testing for air-cooled chillers shall be corrected for air density variations. To accomplish this, use the two correction factors (CF_Q and CF_η) to correct test data at 100 percent load points back to standard barometric pressure at sea level. These correction factors use an empirical method of correction based on industry average values across a wide variety of chillers. The correction factors are based on pressure rather than altitude, in order to include the effects of weather variations. Test data shall be corrected to standard air conditions for comparison to published ratings. The correction multiplier for efficiency and capacity at the 0 (zero) percent load point will be 1.0. Intermediate correction multipliers at part-load points will be a linear interpolation of values between the 0 percent and 100 percent load points where the percent load value is based on the measured capacity divided by the design capacity.

NOTE — These factors are not intended to serve as selection code correction factors. For selection codes it is best to use component models that properly adjust for variation in barometric pressure as related to fan, heat exchanger and compressor power and capacity.

The correction factors (CF_Q and CF_η) will be limited to a value corresponding to a barometric pressure of 84.32 kPa (approximately 1 524 m elevation). Correction factors for measured barometric readings below the minimum will be equal to the value determined at 84.32 kPa.

F-3 PROCEDURE

Air-cooled chillers are tested at the local conditions. The data is then corrected to sea level and standard pressure by multiplying the measured data by the appropriate correction factor (*CF*). Both factors are in the form of a second order polynomial equations, *see* Table 10.

$$D_Q = A_Q.p^2 + B_Q.p + C_Q \quad ...(17)$$

$$D_\eta = A_\eta.p^2 + B_\eta.p + C_\eta \quad ...(18)$$

$$\left(CF_Q\right)_{P=P_{test}} = 1 + \left(\frac{Q \times \%load}{Q \times 100\%}\right).\left(D_Q - 1\right).exp\left\{-0.35 \times \left[\left(3.41214 \times D_\eta \times \eta_{test,100\%}\right) - 9.6\right]\right\} \quad ...(19)$$

$$\left(CF_\eta\right)_{P=P_{test}} = 1 + \left(\frac{Q \times \%load}{Q \times 100\%}\right).\left(D_\eta - 1\right).exp\left\{-0.35 \times \left[\left(3.41214 \times D_\eta \times \eta_{test,100\%}\right) - 9.6\right]\right\} \quad ...(20)$$

$$Q_{corrected,standard} = Q_{test}\left(CF_q\right)_{P=P_{test}} \quad ...(21)$$

$$\eta_{corrected,standard} = \eta_{test}\left(CF_\eta\right)_{P=P_{test}} \quad ...(22)$$

where

P = pressure, absolute, kPa;
Q = capacity, kW;
η = efficiency;
CF_Q = capacity correction factor;
CF_η = efficiency correction factor;
A, *B*, *C* = polynomial constants;
Test = actual measured value during test at local conditions; and
Corrected = adjusted value equivalent to operation at sea level with standard pressure.

100 percent load point example:

A chiller has published ratings of 700.0 kW and 3.100 COPR at sea level. The chiller is tested at an altitude of approximately 1 080 meters.

The measured test results:

Capacity, Q_{tested} = 693.2 kW

Efficiency, η_{tested} = 3.021 COPR

Air pressure, P = 98.07 kPa

Correction function, D_Q = 0.000 023 713 × 98.07² – 0.005 986 0 × 98.07 + 1.363 04 = 1.004 1

Correction function, D_η = 0.000 051 135 × 98.07² – 0.013 064 × 98.07 + 1.798 72 = 1.009 3

Correction function, C_{Fq} = 1 + (693.2/693.2)(1.004 1 – 1) · exp [– 0.35 × (3.412 14 × 1.009 3 × 3.021) – 9.6)] = 1.0031

Correction function, $C_{F\eta}$ = 1 + (693.2/693.2) (1.009 3 – 1) · exp [– 0.35· (3.412 14 × 1.009 3 × 3.021) – 9.6)] = 1.007 0

Corrected test Capacity, $Q_{corrected,standard}$ = 693.2 × 1.003 1= 695.3 kW

Corrected test efficiency, $\eta_{corrected,standard}$ = 3.021 × 1.007 0 = 3.042 COPR

Part load efficiency and capacity correction factors for the following example are determined using the same calculation process as for the 0 percent and 100 percent load point example:

With a part load test result capacity of 560.0 kW and a 693.2 kW test result for 100 percent load point capacity. The chiller is tested at an altitude of about 108 0 meters.

Table 10 Terms Correction Factor (CF) coefficients

(*Clause* F-3)

Sl No.	**Description**			**Unit of Measure**		
	Capacity, D_Q			Capacity, D_η		
	A_Q	B_Q	C_Q	A_η	B_η	C_η
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	2.371 3 E-05	– 5.986 0 E-03	1.363 04 E+00	5.113 5 E-05	– 1.306 4 E-02	1.798 72 E+00

NOTE — E indicates scientific equation, example 1E-02 = 0.01

The measured test results for the part load test:

Capacity, Q_{test} = 560.0 kW

Efficiency, $\eta_{\text{tested,100\%}}$ = 3.021

COP efficiency, η_{test} = 3.686

COP air pressure, P_{test} = 98.07 kPa

Correction function, $D_Q = 0.000\,023\,713 \times 98.07^2 - 0.005\,986\,0 \times 98.07 + 1.363\,04 = 1.004\,1$

Correction function, $D_\eta = 0.000\,051\,135 \times 98.07^2 - 0.013\,064 \times 98.07 + 1.798\,72 = 1.009\,3$

Correction factor, $C_{Fq} = 1 + (560.0/693.2) \cdot (1.004\,1 - 1) \cdot \exp[-0.35 \cdot (3.412\,14 \times 1.009\,3 \times 3.021 - 9.6)] = 1.001\,1$

Correction factor, $C_{F\eta} = 1 + (560.0/693.2) \cdot (1.009\,3 - 1) \cdot \exp[-0.35 \cdot (3.412\,14 \times 1.009\,3 \times 3.021 - 9.6)] = 1.002\,6$

Corrected test capacity, $Q_{\text{corrected,standard}} = 560.0 \times 1.001\,1 = 560.6$ kW

Corrected test efficiency, $\eta_{\text{corrected,standard}} = 3.021 \times 1.002\,6 = 3.029$ COP

ANNEX G

(*Clause* 7.2.2)

WATER-SIDE PRESSURE DROP CORRECTION MEASUREMENT PROCEDURE

G-1 PURPOSE

The purpose of this annex is to prescribe a measurement method for water pressure drop and, when required, a correction method to compensate for friction losses associated with external piping measurement sections. The measurement method only applies to pipe of circular cross section.

G-2 BACKGROUND

As a certified test point for the water to refrigerant heat exchangers, the water-side pressure drop needs to be determined by test with acceptable measurement uncertainty. In some cases, the measured pressure drop as per this standard will be determined by using static pressure taps external to the unit in upstream and downstream piping. When using external piping, adjustment factors are allowed to compensate the reported pressure drop measurement. Numerous studies conclude that the determination of a calculated correction term for these external components may contain significant sources of error and therefore the use of external correction factors will be restricted to limit the magnitude of these potential errors. For units with small connection sizes, it is feasible that straight pipe sections be directly connected to the units with adequate length to obtain static pressure measurements with acceptable systematic errors due to instrument installation location. This is the preferred connection methodology. Units with larger size connections may have spatial limits in the upstream and downstream connection arrangement such that elbows or pipe diameter changes may be necessary to accommodate the available space at the test facility, or to provide mechanical support for piping weight loads.

G-3 MEASUREMENT LOCATIONS

Static pressure taps shall simultaneously meet all of the following requirements:

a) Static pressure taps may be in either the unit connections (that is nozzles) or in additional external piping provided for the purpose of test measurements;

b) If using additional external piping, the piping arrangement shall use rigid pipe and may include fittings such as elbows, reducers, or enlargers between the pressure tap locations and the unit connections. Flexible hose is prohibited between the unit connections and the pressure taps; and

c) Static pressure taps shall maintain the following lengths of cylindrical straight pipe in the flow path adjacent to each pressure tap location in Table 11.

G-4 STATIC PRESSURE TAPS

Static pressure taps will be in a piezometer ring or piezometer manifold arrangement with a minimum of 3 taps located circumferentially around the pipe, all taps at equal angle spacing (*see* Fig. 9). To avoid introducing measurement errors from recirculating flow within the piezometer ring, each of the pipe tap holes shall have a flow resistance that is greater than or equal to 5 times the flow resistance of the piezometer ring piping connections between any pair of pressure taps. A ‘Triple-Tee’ manifold arrangement using 4 pipe tap holes is the preferred arrangement, but not required if meeting the flow resistance requirement (*see* Fig. 10).

G-4.1 For design or evaluation purposes, flow resistance may be estimated by resistance coefficient *K* factor calculation. Generally, manifold tubing or piping can be evaluated using the *K* factor and pressure tap holes can be evaluated using orifice flow equations (*see* **G-5.2**).

G-4.2 Provisions shall be made to bleed air out of the lines connected to pressure measurement devices. These provisions shall take into consideration the orientation of pressure taps and manifold connections.

Table 11 Lengths of Cylindrical Straight Pipe

(*Clause* G-3)

Sl No.	**Unit Connection, Nominal Pipe Size**	**Straight Length in Flow Path**	
		Upstream of Pressure Tap	Downstream of Pressure Tap
(1)	(2)	(3)	(4)
i)	≤ 75 mm	*Min* $10 \cdot D$	*Min* $3 \cdot D$
ii)	100 mm, 125 mm, or 150 mm	*Min* $6 \cdot D$	*Min* $2 \cdot D$
iii)	≥ 200 mm	*Min* $3 \cdot D$	*Min* $1 \cdot D$

where

D = The greatest pipe inside diameter dimension, using the nominal pipe size and pipe schedule nominal wall thickness, of the following locations:

a) The pipe diameter at the pressure tap location;

b) The largest diameter of any reducer or enlarger fittings between the pressure tap location and unit connections; and

c) The largest diameter of the first reducer or enlarger fitting between the pressure tap location and the test facility, if any.

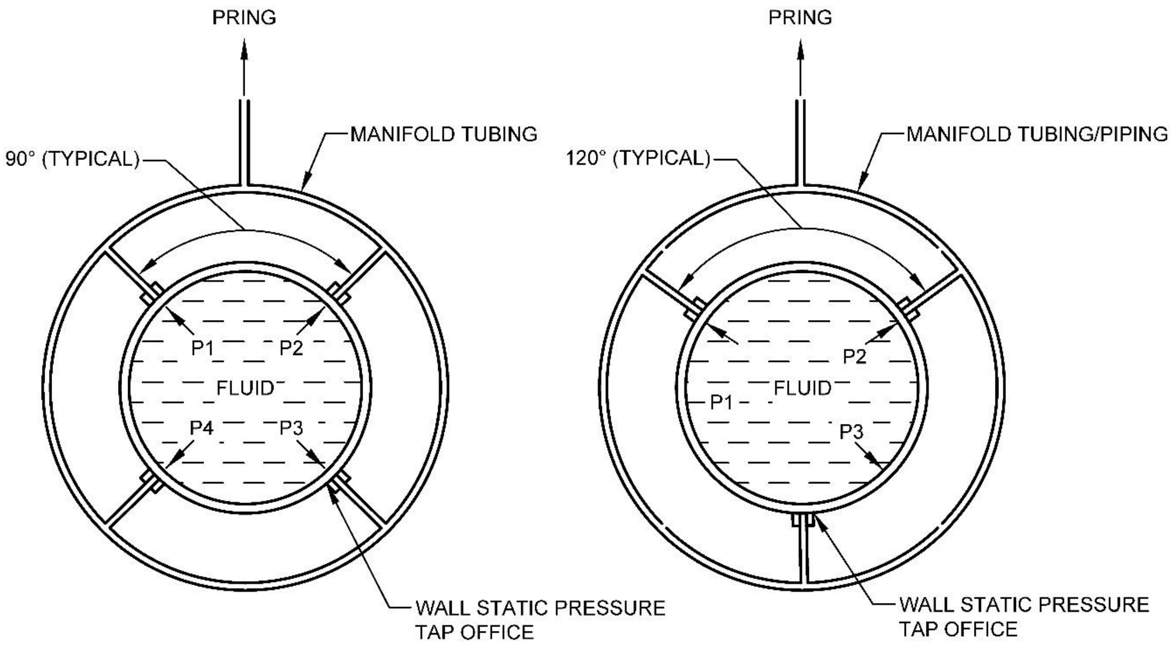

FIG. 9 EXAMPLES OF PIEZOMETER RING/MANIFOLD

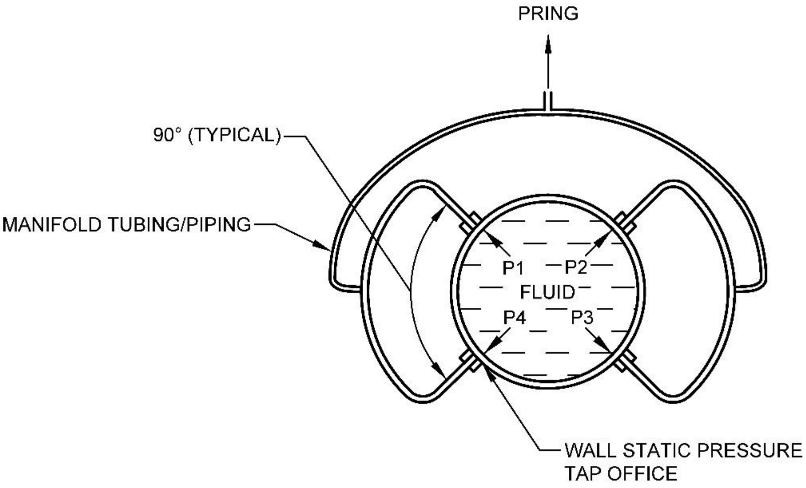

FIG. 10 EXAMPLES OF TRIPLE-TEE PIEZOMETER RING/MANIFOLD

G-5 CORRECTION METHOD

Measured water pressure drop values shall be adjusted to subtract additional static pressure drop due to external piping. The additional static pressure drop shall be the sum of all losses between the unit connections and the location of static pressure taps. Record the original measured value, the calculated adjustment value, and the final calculated result for water pressure drop.

G-5.1 The adjustment shall not exceed 10 percent of the measured water pressure drop.

G-5.2 A Darcy friction factor is determined using the Swamee-Jain equation as given below:

$$F = \frac{0.25}{\left[\log_{10}\left(\frac{\epsilon}{3.7.D} + \frac{5.74}{Re^{0.9}}\right)\right]^2} \quad \text{...(38)}$$

where

ϵ = absolute roughness, 0.045 mm (for purposes of this standard);

D = internal pipe diameter, mm; and

Re = Reynolds number for the flow in the pipe.

The pressure drop (h_L) associated with a flow component or fitting may be calculated using the friction factor as detailed above or the equation may use a *K* factor. These are shown in equations 8 and 9.

$h_L = f.\frac{L}{d}.\frac{V^2}{2g}$ when the Darcy friction factor is used for straight pipe section …(39)

$h_L = K.\frac{L}{d}.\frac{V^2}{2g}$ when a *K* factor is specified for elbows and expansion/contractions …(40)

where

L = pipe length, m;

D = internal Diameter, m;

V = average velocity calculated at the entrance to the component;

G = standard gravitational term 9.81 m/s^2; and

K = resistance coefficient. The K correction factor is computed for the following elbow arrangements as detailed in Table 12.

The determination of the K factor for the expansion and contraction sections is a function of the inlet to outlet diameter ratio as well as the angle of expansion and contraction. The angle of expansion or contraction is detailed on the accompanying chart (Fig. 11) with limits placed at 45° and 10°.

Table 12 K Factors for Elbow Arrangements

(*Clause* G-5.2)

Sl No. (1)	Description (2)	K Factor (3)
i)	Smooth elbow with *r/D* = 1	20.f
ii)	Smooth elbow with *r/D* = 1.5	14·f
iii)	Smooth elbow with *r/D* = 2.0	12·f
iv)	Smooth elbow with *r/D* = 3.0	12·f
v)	Smooth elbow with r/D = 4.0	14·f
vi)	Segmented with 2·45° meters	30·f
vii)	Segmented with 3·30° meters	24·f
viii)	Segmented with 6·15° meters	24·f

where

r = radius of the centerline of the elbow, ft (1ft = 0.30 m)

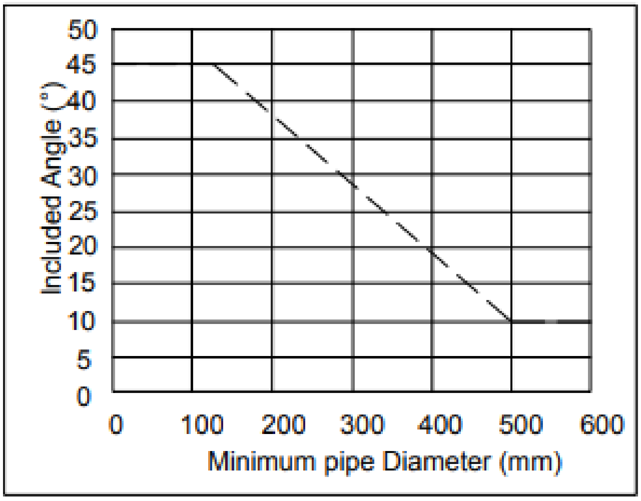

FIG. 11 CORRECTION TERM FOR INCLUDED ANGLE FOR EXPANSION/CONTRACTION FITTING

ANNEX H

(*Foreword*)

COMMITTEE COMPOSITION

Refrigeration and Air Conditioning Sectional Committee, MED 03

Organization	*Representative(s)*
Indian Institute of Technology Roorkee	Prof Ravi Kumar **(*Chairperson*)**
Blue Star Limited, Mumbai	Shri Jitendra Bhambure Shri Sunil Kumar Jain (*Alternate*)
BSH Household Appliances Manufacturing Private Limited, Chennai	Shri Loganathan Vijay Kumar Shri Balasubramanian Anand (*Alternate*)
Bureau of Energy Efficiency, New Delhi	Ms Pravatanalini Samal Ms Deepshikha Wadhwa (*Alternate* I) Shri Kamran Shaik (*Alternate* II) Shri Dheeraj Pandey (*Alternate* III)
Carrier Air Conditioning and Refrigeration Limited, Gurugram	Shri Bimal Tandon Shri Manmohan Kulashri (*Alternate* I) Shri Jatinder Sharma (*Alternate* II)
Central Power Research Institute, Bengaluru	Dr P. Chandra Sekhar Shri Gujjala B. Balaraja (*Alternate*)
CEPT University, Ahmedabad	Shri Yash Shukla
Copeland India Private Limited, Pune	Shri S. Chethan Tholpady
Daikin Air Conditioning India Private Limited, Gurugram	Shri Gaurav Mehtani
Danfoss Industries Private Limited, Gurugram	Shri Madhur Sehgal Shri K. L. Nagahari (*Alternate* I) Shri M. N. S. V. Kiran Kumar (*Alternate* II)
Directorate General of Quality Assurance, Ministry of Defence, New Delhi	Lt Col Deepak Sharma Shri S. S. Nikam (*Alternate*)
Electrical Research and Development Association, Vadodara	Shri Guatam Brahmbhatt Shri Rakesh Patel Singh (*Alternate*)
Emerson Climate Technologies (India) Private Limited, New Delhi	Shri Chethan Tholpady Shri D. P. Despande (*Alternate*)
Frigoglass India Private Limited, Gurugram	Shri Mahesh Kumar Mawai Shri Mandeep Singh (*Alternate* I) Ms Ritu Chouhan (*Alternate* II)
Godrej & Boyce Manufacturing Company Limited, Mumbai	Shri Burzin Wadia Shri Jasvir Singh (*Alternate* I) Shri Narendra Shedge (*Alternate* II)
Honeywell International India Private Limited, Gurugram	Shri Aaditya Pegallapati Shri Avinash Kumar (*Alternate*)

Organization	*Representative(s)*
Indian Institute of Chemical Engineering, Kolkata	Dr D. Sathiyamoorthy Dr Sudip K. Das (*Alternate*)
Indian Institute of Technology Madras, Chennai	Dr G. Venkatarathnam
Indian Society of Heating, Refrigerating and Air Conditioning Engineers, New Delhi	Dr Jyotirmay Mathur Shri Ashish Rakheja (*Alternate* I) Shri V. Manjunath (*Alternate* II)
Ingersoll Rand India Limited, Bengaluru	Shri M. Venkanna Shri J. Gurusamy (*Alternate*)
International Copper Association India, Mumbai	Shri Mayur Karmakar Shri Shankar Sapaliga (*Alternate*)
Intertek India Private Limited, Gurugram	Shri C. M. Pathak
Johnson Controls-Hitachi Air Conditioning India Limited, Mehsana	Shri Rahul Ramtekkar Ms Heena Ramsinghani (*Alternate*)
LG Electronics India Private Limited, New Delhi	Shri Aditya Anil
Refrigeration and Air Conditioning Manufacturers Association, New Delhi	Shri Kanwaljeet Jawa Shri Harsh Vardhan Pant (*Alternate*)
Samsung India Electronics Private Limited, New Delhi	Shri Kalicharan Sahu Shri Amit Kumar Jha (*Alternate*)
Sierra Aircon Private Limited, Gurugram	Shri D. K. Mudgal Shri S. Dhiman (*Alternate*)
The Chemours India Private Limited, Gurugram	Shri Vikas Mehta Shri Nishit Shah (*Alternate*)
UL India Private Limited, Bengaluru	Shri V. Manjunath Shri Satish Kumar (*Alternate*)
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Voluntary Organisation in Interest of Consumer Education (VOICE), New Delhi	Shri B. K. Mukhopadhyay Shri H. S. Wadhwa (*Alternate*)
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Panel for Revision of IS 16590, MED 03 : P19

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Indian Society of Heating, Refrigerating and Air Conditioning Engineers, New Delhi	DR JYOTIRMAY MATHUR **(*Co-convener*)**
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Emerson Climate Technologies (India) Private Limited, New Delhi	SHRI CHETHAN THOLPADY
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Johnson Controls-Hitachi Air Conditioning India Limited, Mehsana	SHRI RAHUL RAMTEKKAR
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(*Continued from second cover*)

ANSI/ASHRAE Standard 37-2009	Method of testing for ratings electrically driven unitary air conditioning and heat pump equipment
ASHRAE Standard 116-2010	Methods of testing for rating for seasonal efficiency of unitary air conditioners and heat pumps
ASHRAE Standard 51-16 - 2016	Laboratory methods of testing fans for certified aero- dynamic performance rating
AMCA Standard 210-2016	Laboratory methods of testing fans for certified aerodynamic performance rating

This standard contributes to the sustainable development goal 9 — Industry, innovation and infrastructure: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.

The composition of the Committee responsible for the formulation of this standard is given in Annex H.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 ‘Rules for rounding off numerical values (*second revision*)’. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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